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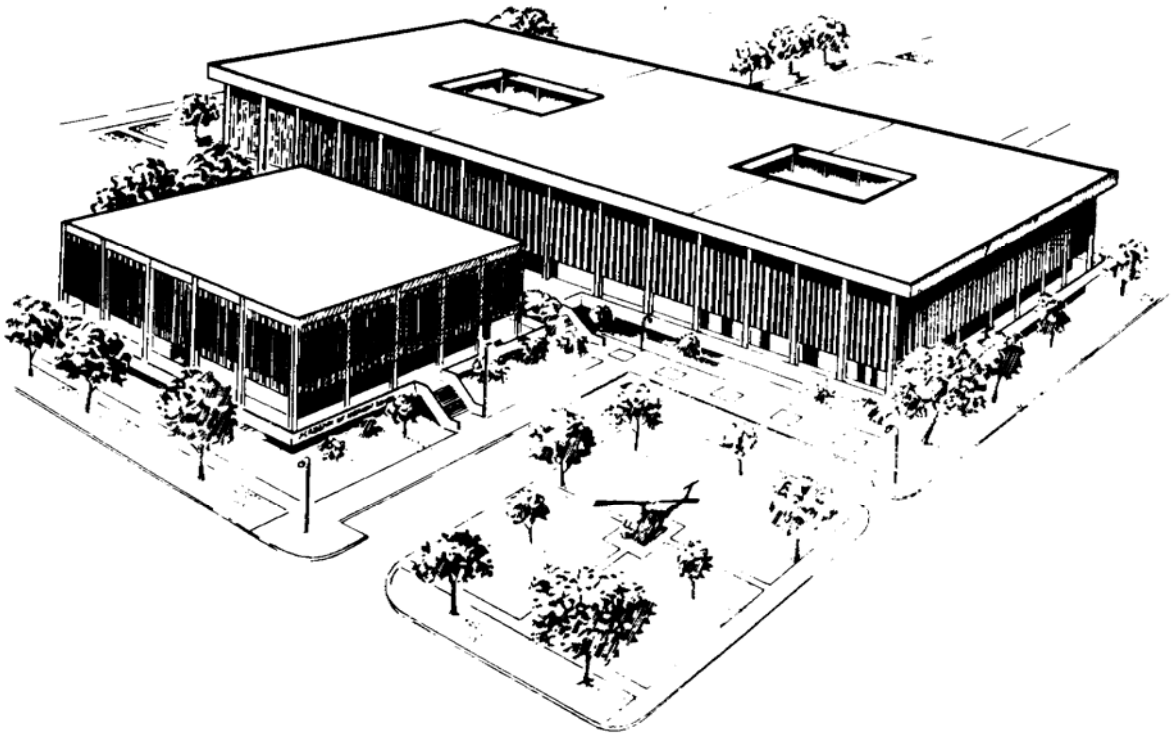
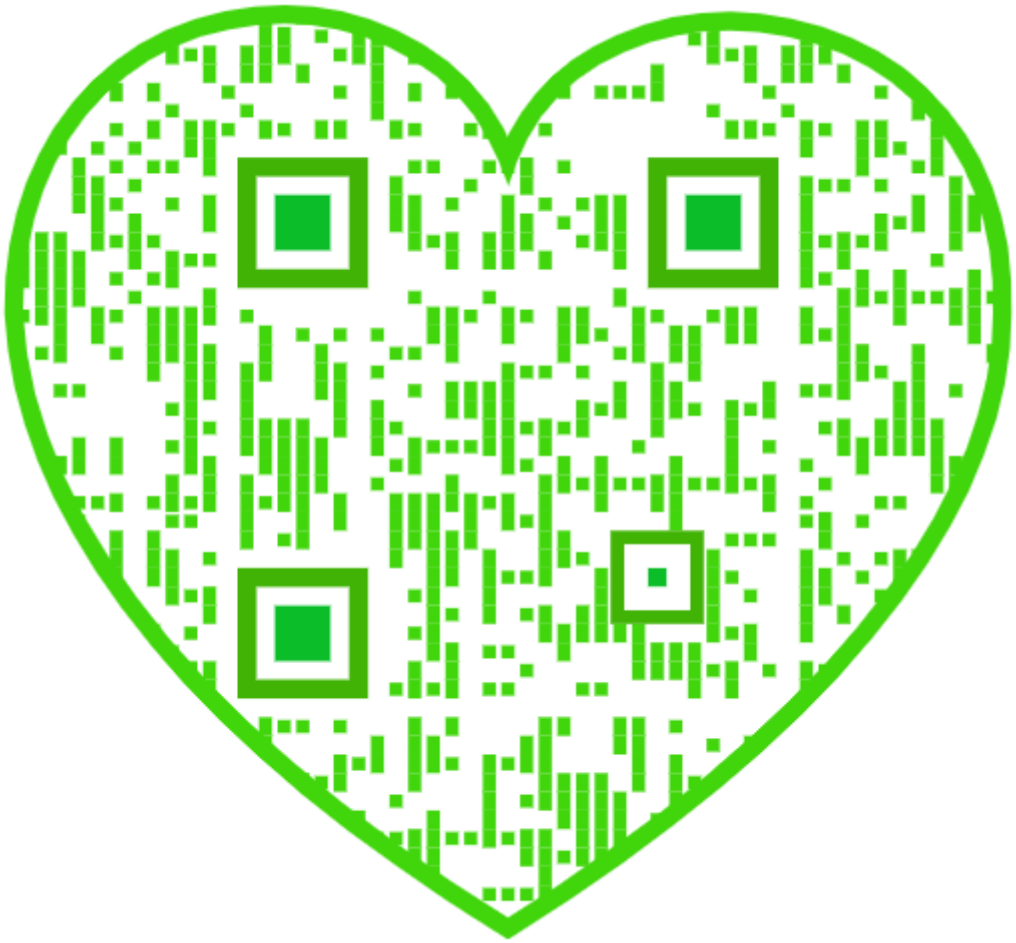


BLOOD, ELECTROLYTES, AND INTRAVENOUS INFUSIONS

SUBCOURSE MD0564 EDITION 200



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When used in this publication, words such as "he," "him," "his," and "men" are intended to include both the masculine and feminine genders, unless specifically stated otherwise or when obvious in context.

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CORRESPONDENCE COURSE OF THE
U.S. ARMY MEDICAL DEPARTMENT CENTER AND SCHOOL

SUBCOURSE MD0564

BLOOD, ELECTROLYTES, AND INTRAVENOUS INFUSIONS

INTRODUCTION

This subcourse is concerned with knowledge that is vital in order to understand the "whys" and "hows" for using the intravenous route to administer the kinds of fluids that can save life and limb. You should possess the knowledge to correct and expand on the medical procedures used by the Combat Medical Specialist and also have the ability to interact with the physicians and physician assistants who will have the final responsibility for treating battle injuries and illnesses.

Some of the terms used in this course may be unfamiliar to you. You will have frequent contact with the physician and physician assistants and will need to understand their vocabulary. It would be wise to use one of the excellent medical dictionaries available in most bookstores and libraries. Some examples are the latest editions of Dorland's Illustrated Medical Dictionary (published by W. B. Saunders Company) or Taber's Cyclopedia Medical Dictionary (published by F. A. Davis Company). For general English usage, an example is Webster's New Collegiate Dictionary (published by G. and C. Merriam Company). Do not feel restrained by these examples. Any good dictionary will be useful.

For your convenience, we have included a glossary of special terms in the appendix at the end of this subcourse. Take a few minutes to read this glossary before you start the lessons. It may save you some dictionary time later.

We suggest that you do not attempt to master large amounts of this information at one sitting. This would be especially difficult if some of the material is new to you.

Contained in the third chapter is the currently accepted method for starting and for discontinuing an intravenous infusion and a blood transfusion. Mastery of this section is not enough to begin giving infusions and transfusions. You must be trained under the supervision of a person who is qualified to instruct you in these processes, supervise your practice, and evaluate your skills and abilities very carefully.

Subcourse Components:

This subcourse consists of three lessons and an appendix. They are:

Lesson 1, Human Blood.
Lesson 2, Fluids and Electrolytes.
Lesson 3, Intravenous Preparations and Methods for Administration.
Appendix: Glossary of Terms.

Credit Awarded:

To receive credit hours, you must be officially enrolled and complete an examination furnished by the Nonresident Instruction Section at Fort Sam Houston, Texas. Upon successful completion of the examination for this subcourse, you will be awarded six credit hours.

You can enroll by going to the web site http://atrrs.army.mil and enrolling under "Self Development" (School Code 555).

A listing of correspondence courses and subcourses available through the Nonresident Instruction Section is found in Chapter 4 of DA Pamphlet 350-59, Army Correspondence Course Program Catalog. The DA PAM is available at the following website: http://www.usapa.army.mil/pdffiles/p350-59.pdf.

LESSON ASSIGNMENT

LESSON 1	Human Blood.
TEXT ASSIGNMENT	Paragraphs 1-1 through 1-11.
LESSON OBJECTIVES	After completing this lesson, you should be able to:
	1-1. Identify the properties and functions of blood.
	1-2. Identify the three types of blood cells by their names, functions, and properties.
	1-3. Identify the mechanisms of hemostasis.
	1-4. Identify the types or groups of human blood and their importance.
SUGGESTION	After completing the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 1

HUMAN BLOOD

Section I. BLOOD PARTS

1-1. INTRODUCTION

Adequate substitutes for human blood do not exist. There are many kinds of blood expanders, blood thinners, and aids for ailing blood, but none of these can substitute for the unique properties and functions of blood in the human body. Without sufficient human blood, our bodies would stop functioning. This is why the blood banks make frequent requests for donations from healthy individuals. As a medical noncommissioned officer (NCO), you will be expected to perform your duties in peacetime and on the field of battle. Your subordinates will often ask why certain functions must be done. Using the knowledge contained in this lesson, you will have the answers for questions about human blood.

1-2. PROPERTIES AND FUNCTIONS OF THE BLOOD

a. **Amount.** Blood accounts for 7 to 9 percent of the body weight. A person weighing 150 pounds will have about 4 to 6 liters of blood. The actual amount of blood in each person's body is affected by several factors, such as body size and age. The older the person, the less blood in his body. A big person has more blood than a small person and, all else being equal, a male has more blood than a female.

b. **Functions.** Blood is constantly in motion. Asleep or awake, the blood flows in a circulation system at almost the same rate. This process begins before we are born and does not stop until after death. Blood flows in virtually a closed system to all tissues of the body. It brings oxygen and nutritive substances to the capillaries (smallest blood vessels) and removes metabolic waste products and carbon dioxide, which are then eliminated from the body by the excretory organs. The blood coordinates activities of various organs by carrying chemical regulators called hormones. See paragraph 2-14 for a discussion of hormones. Blood regulates body temperature and protects the body against disease. Blood maintains acid-base equilibrium of the body (about pH 7.35 in the veins and about pH 7.39 in the arteries). See paragraph 2-6 for a discussion of acid-base balance.

c. **Major Components.** Blood has a liquid portion and a solid portion. The liquid portion is called plasma, which is about 55 percent of the blood's volume. The solid portion (red cells, white cells, and other vital factors) makes up the remaining 45 percent.

1-3. BLOOD CELLS

The cells contained in the blood are of two main types: red blood cells (erythrocytes) and white blood cells (leukocytes). The erythrocytes are produced in the red bone marrow that is primarily present (in the adult body) in the sternum, ribs, hipbones, and cranial bones. Most of the granular leukocytes are also formed in the red bone marrow. Most of the non-granular leukocytes are formed in the lymph nodes, thymus gland, and the spleen.

a. **Erythrocytes.** The erythrocyte is the red blood cell (RBC) of the blood. The mature RBC contains about 34 percent hemoglobin (a complex iron-bearing protein which transports gases). Erythrocytes are produced primarily in the red marrow of the spongy bones. Hemoglobin is the main functioning component of the cell. The RBCs transport oxygen from the lungs to the tissues and carbon dioxide from the tissues to the lungs. The hemoglobin protein is composed of carbon, nitrogen, and iron. Hemoglobin carries 98 percent of the oxygen. Less than 2 percent is carried in simple solution in the plasma. These cells have an average life span of 80 to 120 days. When a red blood cell becomes too old, it is broken down into its elements (especially in the spleen). A portion is carried to the liver and excreted as "bilirubin" with the bile. This gives the bile its golden-yellow color. The iron is retained and either reused or stored for future use. (See figure 1-1.)

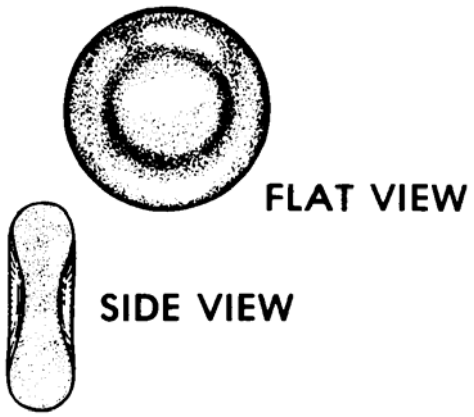

Figure 1-1. Red blood cells.

b. **Leukocytes.** There are two main groups: granular and nongranular leukocytes. These are further subdivided into neutrophils, eosinophils, and basophils, which are granular. Nongranular are classed as lymphocytes and monocytes.

(1) General functions. The leukocytes remove invading antigens (that is, bacteria) and, to some extent, transport and distribute antibodies. In antigen removal, some nongranular and granular leukocytes show directional movement, subject to chemical stimulus (chemotaxis). In this way, they are attracted to substances, which they must either transport or engulf. The process of engulfing and destroying bacteria (phagocytosis) is the prime function of leukocytes. (See figure 1-2.)

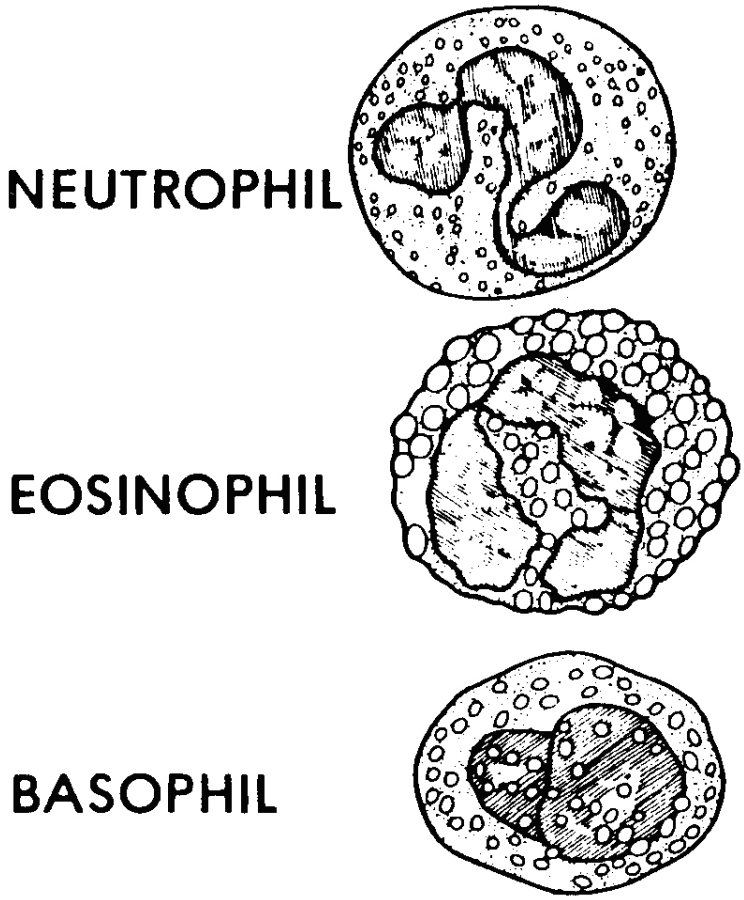

Figure 1-2. Leukocytes-granular.

(2) Types and their specific functions. The three types of polymorphonuclear (called polys or granular) are neutrophils, esoinophils, and basophils. The neutrophils increase in number when fighting pyrogenic infections (fever producing). They decrease in number when reacting to toxic substances. This can occur with certain drugs. The esoinophils will increase in reaction to allergy or parasitic infections, and they will decrease in reaction to adrenocortical hormones. The basophils will increase in the presence of leukemia (but their exact function is not known). Lymphocytes and monocytes are nongranular leukocytes. The lymphocytes are believed to be directly involved with the antibody production. They increase in number in the presence of certain infections such as mononucleosis. Monocytes will increase during tuberculosis and protozoal infections. All types of leukocytes will increase during leukemia and will decrease because of acquired immunodeficiency syndrome (AIDS). (See figure 1-3.)

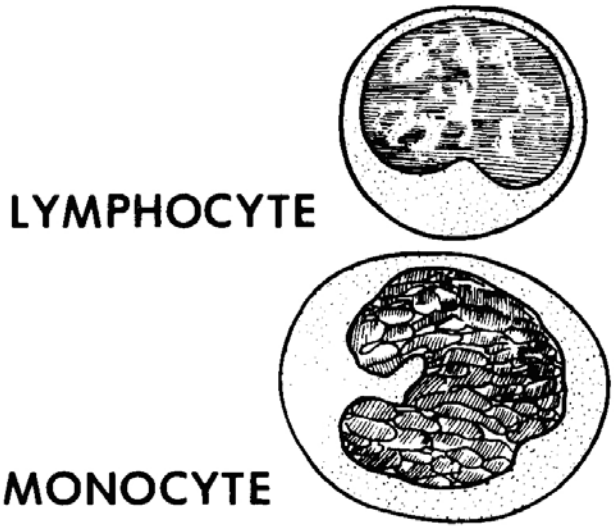

Figure 1-3. Leukocytes-nongranular.

c. **Thrombocytes.** Thrombocytes are commonly called "platelets." They are detached irregular shaped fragments of their precursor cells (which are found in the bone marrow). These precursor cells are giants in size compared to the other blood cells. The platelets live for only 3 to 5 days. The platelets contain different clotting factors and other components that are either known or presumed to participate in the clotting process. They clump together to form a plug in the initial phase of controlling bleeding. This process is speeded up by thrombin, an enzyme involved in blood clotting. A deficiency in platelets causes a tendency to bleed. The platelets possess ameboid movements. This property is very necessary for the clotting process. (See figure 1-4.)

Figure 1-4. Platelets.

Section II. FUNCTION OF THE BLOOD IN TRAUMA-HEMOSTASIS

1-4 INTRODUCTION

Hemostasis (the arrest of bleeding) has three separate mechanisms--platelet clumping (agglutination), contracting of blood vessels, and forming a fibrin clot.

1-5. TEMPORARY PLUG

When either a vein or an artery (not a capillary) is cut or damaged, platelets begin to accumulate rapidly at the site of injury and cling to the interior blood vessel wall. These form a temporary plug that can stop the bleeding.

1-6. MUSCLE CONSTRICTION

At the same time, the muscles of the damaged vessel constrict. Shortly after the first plug forms, platelets fuse into a dense mass. This mass forms a temporary solid seal at the injury site. As the platelets agglutinize (clump), a second type of constriction occurs. The platelets release a chemical called "serotonin." This chemical causes the second type of constriction of the injured and neighboring blood vessels. After this series of platelet changes, the clotting mechanism occurs.

1-7. CLOT FORMATION

The soluble protein "fibrinogen" is transformed into the insoluble "fibrin" in a very complex, but rapid, process. Besides the fibrinogen, the clotting process requires prothrombin (which is converted into thrombin), vitamin K, calcium, thromboplastin, and many other factors that participate in the clotting process. When the platelets stick to the surface of the damaged vessel, calcium ion, and active thromboplastin are released from the cells and split prothrombin into two parts. One of these parts is thrombin. When thrombin is released from the prothrombin, it transforms the fibrinogen into fibrin.

a. The fibrin becomes a network of fibers or threads that trap blood cells, platelets, and plasma to form the blood clot. Calcium ions appear necessary for the operation of the sequence that results in the release of thrombin from prothrombin.

b. The synthesis of prothrombin and some of the other clotting process factors takes place in the liver. Vitamin K is needed for the liver to produce these factors. If any of these factors are in short supply or absent, the person would have a tendency to bleed. This is characteristic of a genetically transmitted disease called "hemophilia."

c. This clotting process is the same one that causes a thrombus (blood clot) to form in the blood vessels of the leg or arm. Normally, the body contains the factor "heparin" in the tissues. This substance is produced in many organs of the body, and it prevents clotting in the absence of blood vessel damage. If there is a breakdown in this system, the drug "dicumarol" can be used clinically as an anticoagulant. It blocks the stimulating effect of vitamin K on the liver. Therefore, the liver produces less prothrombin, and the blood loses its tendency to form thromboses.

Section III. BLOOD TYPES OR GROUPS

1-8. MAJOR GROUPS

Before being used for a transfusion, blood must be typed and cross-matched to assure compatibility between the blood of the person who gets the transfusion and the type of blood being used. The most well known of the groupings is the A-B-O group.

1-9. A-B-O GROUP

Each person has either type A, B, AB, or O. The most common types in America are type 0 (45 percent) of the population and type A (41 percent). The blood type indicates the presence or absence of certain antigens. These antigens stimulate the body to produce antibodies. The antibodies react with their antigens to form agglutination or little clusters (clumps) in the blood. When a person has type A blood, his blood contains antibodies for type B, but none for type A. The opposite is true if he has type B blood. That is, the person would have antibodies for type A, but none for type B. If a person has type AB blood, he has neither type A nor type B antibodies and can receive type A, B or AB blood. Type O blood causes no antibodies to be formed and thus can be used to infuse any A-B-O group person. Figure 1-5 shows these relationships.

PERSON TO RECEIVE TRANSFUSION IS TYPE:

The Person Who Donates the Blood is Type:	A	B	AB	O
A	yes	no	yes	no
B	no	yes	yes	no
AB	no	no	yes	no
O	yes	yes	yes	yes

Figure 1-5 Blood types and compatible transfusions.

a. A type AB person is generally called "the universal recipient," and a person with type O blood is generally called the "universal donor."

b. A universal recipient is a person whose blood does not try to fight off the blood cells from any A-B-O source. Thus, it makes no difference which A-B-O type blood he receives. He can generally accept them all without adverse effect.

c. A universal donor is a person whose blood is well accepted by any A-B-O type person. This blood generally causes no adverse effects on the blood of any A-B-O type person who receives it. Because of this unique property, the universal donor is frequently asked to make blood donations.

1-10. Rh FACTOR

Many other flood factors have been isolated. The first one discovered (and the most important one) is the Rhesus (Rh) factor. The name "Rhesus" is taken from the name of the Indian rhesus monkey. This factor was first isolated from experiments with these monkeys. Each person is either Rhesus positive or Rhesus negative, depending on whether he has or does not have antigens for the Rh factor. Rh-positive people have these antigens while Rh-negative people do not (unless they have been transfused with Rh-positive blood). The amount of transfusion required to produce this reaction varies with the individual. A true "universal donor" would generally be type O and Rh-negative. Serious problems because of the Rh factor can occur during pregnancy if the mother is Rh-negative and he fetus is Rh-positive. Small numbers of the child's red cells escape from the placenta and enter the mother's blood stream. This will cause no problem during the first pregnancy, but she will form antibodies. If she is also carrying a Rh-positive child during the second or subsequent pregnancies, the antibodies from her blood will attack the blood of the fetus and cause anemia in the fetus. Some possibilities are open for countering this problem. The baby can be transfused with Rh-negative blood at birth or anti-Rhesus immune globulin injections can be given to the mother. The stage of the pregnancy when the situation is discovered will usually determine which procedure should be used.

1-11. OTHER BLOOD GROUPS

Other factors (or groups) have varying effects on the blood, but none have the impact of the A-B-O or the Rh factors. These factors have names such as "Cartwright," "MN," "Lewis," "He," "Kell," and "Wright." Some factors may cause hemolytic disease in newborns. Some of these factors may present problems in organ transplants. The incidence of problems is normal use for blood transfusions is rare, but hemolytic reactions should be monitored during all blood transfusions. These other factors are sometimes used to establish or reject the possibility of familial relationships, such as in cases of disputed fatherhood.

Continue with Exercises

EXERCISES, LESSON 1

INSTRUCTIONS: Answer the following exercises by marking the lettered response that best answers the exercise, by completing the incomplete statement, or by writing the answer in the space provided at the end of the exercise.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. How are waste products removed from the body's cells?

   _____

   _____

2. The solid portion makes up what percentage of the blood?

   a. 55 percent.

   b. 45 percent.

   c. 7 percent.

   d. 73.5 percent.

3. The spleen is an important source of:

   a. Erythrocytes.

   b. Granular leukocytes.

   c. Non-granular leukocytes.

   d. Red bone marrow.

4. The main functioning part of the red blood cell is the:

    a. Hemoglobin.

    b. Bilirubin.

    c. Erythrocyte.

    d. Red bone marrow.

5. All types of leukocytes will increase due to:

    a. Reaction to toxic substances.

    b. AIDS.

    c. The presence of thrombin.

    d. Leukemia.

6. The prime function of the leukocyte is to:

    a. Form a scab following injury.

    b. Destroy bacteria.

    c. Build bones and teeth.

    d. Transport iron.

7. The chemical which is released from the platelets to cause constriction in trauma is:

    a. Folic acid.

    b. Fibrinogen.

    c. Prothrombin.

    d. Serotonin.

8. To form a blood clot, blood parts are trapped in a thread network made of:

   a. Prothrombin.

   b. Thromboplastin.

   c. Fibrin.

   d. Plasma.

9. Dicumarol is frequently prescribed to:

   a. Aid in clot formation.

   b. Induce vessel constriction.

   c. Stimulate the liver.

   d. Block vitamin K action.

10. The most destructive mismatch of any blood group, for transfusion purposes, is the group called:

    a. Rh.

    b. Cartwright.

    c. A-B-O.

    d. MN.

11. Why is there a difference between a universal donor (blood type O) and a true universal donor (blood type O Rh-negative)?

    _____

    _____

    _____

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 1

1. Waste products are picked up by the capillaries and transported by the blood to the excretory organs that then eliminate them from the body. (para 1-2b and glossary)

2. b (para 1-2c)

3. c (para 1-3)

4. a (para 1-3a)

5. d (para 1-3b(2))

6. b (para 1-3b(1))

7. d (para 1-6)

8. c (para 1-7a)

9. d (para 1-7c)

10. c (para 1-9) Note: This conclusion can be drawn from the fact than no other blood group mismatch will cause the blood to agglutinize.

11. A universal donor's blood can be generally accepted, without adverse effect, by a person with any A-B-O blood type. If the blood transfused is type O Rh-positive and the recipient is an Rh-negative female, it can cause her blood to develop antibodies. These antibodies will fight the blood of an Rh-positive fetus she may carry during pregnancy. (para 1-10)

End of Lesson 1

LESSON ASSIGNMENT

LESSON 2 Fluids and Electrolytes.

LESSON TEXT Paragraphs 2-1 through 2-14.

LESSON OBJECTIVES After completing this lesson, you should be able to:

2-1. Identify the proportions and balancing mechanisms for fluid in the body.

2-2. Identify the categories of body fluids by their proportions and functions.

2-3. Identify the uses for electrolytes in body fluids.

2-4. Identify the body's requirements for an acid-base balance.

2-5. Identify the directional movements of the intravenous solutions.

2-6. Identify the difference between diffusion and osmosis.

2-7. Identify the difference between crystalloid and colloid solutions.

2-8. Identify the body's routes of normal and abnormal fluid loss and replacement measures for these fluids.

2-9. Identify the functions of enzymes and hormones.

SUGGESTION After completing the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 2

Section I. BODY FLUIDS

2-1. INTRODUCTION

The human body can continue to function much longer without food than without water. Although a person deprived of food for extended periods may experience hunger pangs (and even undergo personality changes), his body will continue to function well enough to permit some use of all faculties. After a time, even this limited use will fade, but this may take weeks or months. The lack of water can cause death within days or even hours (in some cases). The reasons for this situation will be shown in Lesson 2. All animals require a water environment. In the case of marine animals, the water surrounds them. In the case of land animals, the water is carried within the body. Homo sapiens (human beings) are no exception. Water supports life. The lack of water destroys life. The percentages and fractions listed in this lesson may vary, depending on the reference that you consult. This is caused by the different methods of measurement used by the research laboratories. The variations from one reference to another are slight and do not affect the general concept.

2-2. NORMAL FLUID CONTENT IN THE BODY

The average 70 kilogram (or 154 pound) adult male's body weight is approximately 60 to 70 percent water (see figure 2-1). The more a person weighs (not including body fat), the more water his body contains. The more fat is present in the body, the less will be the total water content per unit of body weight. Fat has almost no water, so fat people have lower water content per pound of body weight than slender people. Water may account for 50 percent or less of their body weight. A newborn infant may have 80 percent of total body weight in water. This proportion decreases gradually as the child grows older and fat is added to the body.

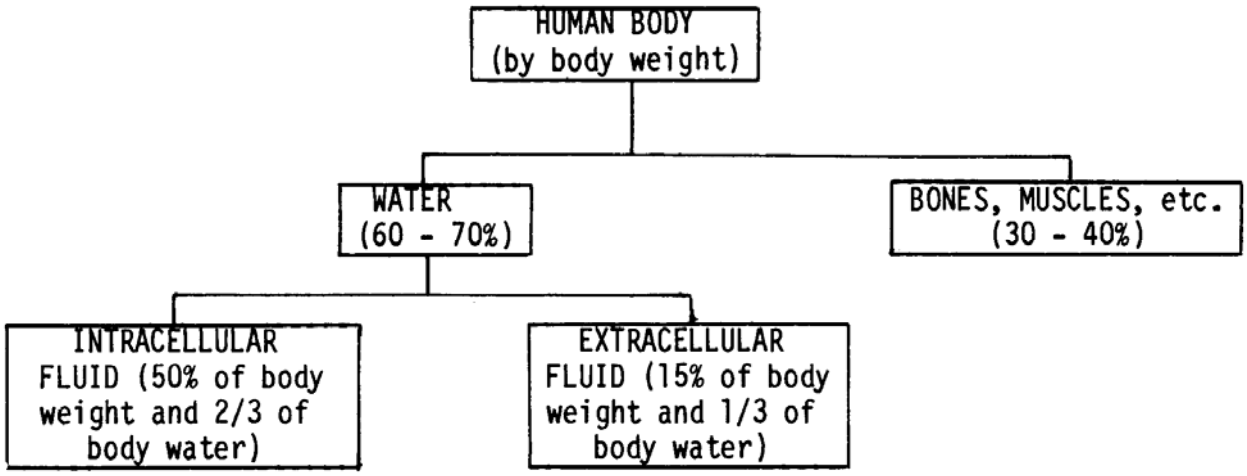

Figure 2-1. Body water by body weight.

2-3. PROCESSES FOR MAINTAINING WATER BALANCE

The body must maintain fluid balance to achieve homeostasis. The body achieves this balance by adjusting fluid output to equal fluid intake so that the amount of water in the body does not change. We have three sources of fluid intake: the fluids we drink, water in the foods we eat, and water formed by catabolism of tissues. Fluid output is regulated by four organs: the kidneys (which excrete urine), the lungs (which exhale moisture, carbon dioxide, and air), the skin (which excretes perspiration), and the intestines (which excrete moisture in the feces). The volume of urine excreted is the most subject to change. The more fluid the person drinks, the greater the volume of urine excreted; the less fluid consumed, the less the urine flow. This urine regulation is accomplished by a hormone present in the blood stream.

2-4. CATEGORIES OF FLUIDS

Body water is divided into two primary types--intracellular fluid (ICF) and extracellular fluid (ECF). The intracellular is fluid that is contained within the body's cells. The fluid within the cells makes up about 2/3 of a person's total body water and accounts for about 50 percent of the person's body weight. The extracellular fluid is located in the body tissues, bones, and the body's vascular systems (blood and lymph). The fluids discussed thus far can be depicted as shown in figure 2-1.

a. The intracellular fluid functions in three ways. It transports food within the cells. It brings waste products from the cells so that they can be picked up and excreted from the body. This fluid also maintains the integrity (shape and size) of the cell.

b. The second type of body fluid is the extracellular fluid. The intracellular fluid is located outside the body cells. The extracellular fluid (ECF) comprises approximately one-third of the water contained in the body, and it accounts for approximately 15 percent of a person's body weight. The extracellular fluid has several functions. It carries nutrients and oxygen to the cells and waste materials from the cells. It serves to bathe the cells in order to keep the cells moist. Two divisions or types of extracellular fluid are interstitial fluid and intravascular fluid. The interstitial fluid surrounds cells and it serves as a transporting medium to carry materials to and from cells. Approximately three fourths of the extracellular fluid is contained in the interstitial fluid. Interstitial fluid accounts for approximately 11 percent of a person's body weight. The second division of the extracellular fluid is the intravascular fluid (one-fourth of the extracellular fluid). The intravascular fluid is found in the body's circulatory systems. It accounts for approximately four percent of a person's body weight (see figure 2-2).

c. Body water diffuses throughout the body without recognizing anatomic boundaries. For example, water passes constantly across the tissue surface of the capillaries. If we could label all the water molecules by the function they were serving at a particular moment (interstitial, intravascular, and so forth), within another minute about half of them would be in another location or serving another function. There is an especially constant circulation of water (and the substance dissolved in it) between the fluids surrounding the cells and the blood.

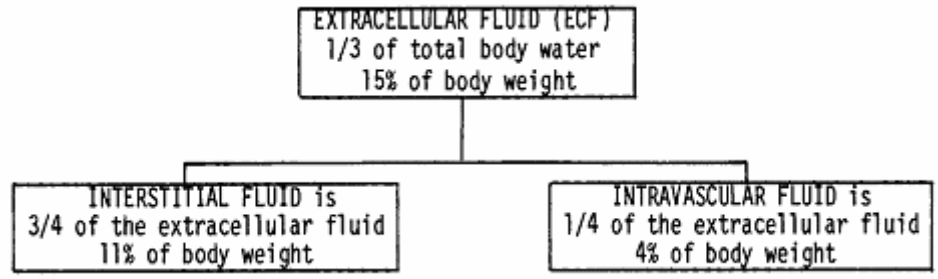
EXTRACELLULAR FLUID (ECF)
1/3 of total body water
15% of body weight
INTERSTITIAL FLUID is
3/4 of the extracellular fluid
11% of body weight
INTRAVASCULAR FLUID is
1/4 of the extracellular fluid
4% of body weight

Figure 2-2. Extracellular fluid distribution.

Section II. ELECTROLYTES IN BODY FLUIDS

2-5. ELECTROLYTES

The amounts of intracellular and extracellular fluids contained in a person's body are extremely important to his healthy physiology. Losses of body fluids by vomiting, diarrhea, or excessive perspiration can produce illness or even death. Whenever body fluids are lost, the substances dissolved in the fluids are also lost. Certain inorganic substances are found in the body's fluids. These are called "electrolytes." Examples of electrolytes are potassium and chloride. These electrolytes exist in their "ion" state in the body fluids. This means that each ion can combine with one or more ions to form needed body compounds or can produce electro-chemical equilibrium (or balance). One example of this is the osmotic pressure that causes water to flow across a cell membrane. The relationship between the concentrations of sodium and potassium electrolytes in the cells and the extracellular fluid causes the water to flow into and out from the cells. There is usually a low level of sodium in the cells and a high concentration of potassium. The milliequivalent (mEq) is a unit of measure for the electrolyte.

a. The movement of electrolytes is governed by their electrical charge. Some are positively charged and are called "cations." Others are negatively charged and called "anions." Below are the major electrolytes, their chemical abbreviations, and the amount of each contained in a liter of extracellular fluid.

Sodium (Na^{+})	140 mEq
Chloride (Cl^{-})	100 mEq
Bicarbonate (HCO_3^{-})	27 mEq
Potassium (K^{+})	4 mEq
Magnesium (Mg^{+2})	3 mEq

(1) Certain compounds can be formed by combining these charged cations and anions.

(a) To form magnesium chloride:

Each ion of magnesium has two positive charges (Mg^{+2}). There are 3 mEq of magnesium in each liter of extracellular fluid. Therefore, each liter of extracellular fluid has 6 positive ions of magnesium ($^{+}2 \times 3 = {}^{+}6$) available to combine with other negative ions. If the compound, magnesium chloride is needed, these six positive ions could combine with six negative ions from the 100 mEq of chloride contained in a liter of extracellular fluid (each electrolyte of chloride has one negative charge, shown as Cl^{-}). This would yield the required magnesium chloride by neutralizing the positive and negative ions.

(b) To form sodium bicarbonate:

Each ion of sodium has one positive charge (Na^{+}). There is one negative charge of bicarbonate (HCO_3^{-}) in each ion of bicarbonate. If the compound, sodium bicarbonate is required, each positive sodium ion can combine with a negative bicarbonate ion to yield the required amount of sodium bicarbonate. This neutralizes the positive and negative ions of both the sodium and the bicarbonate used.

(2) When the body loses fluids, the number and kind of electrolyte(s) lost will depend on whether the fluid has been lost from interstitial or intravascular spaces or both.

b. Intracellular fluid contains the following kinds and amounts of electrolytes per liter:

Potassium (K^{+})	160 mEq
Phosphate (PO_4^{-3})	110 mEq
Magnesium (Mg^{+2})	25 mEq
Sodium (Na^{+})	5 mEq
Chloride (Cl^{-})	3 mEq

c. Each electrolyte has certain functions in order to help the body maintain homeostasis.

(1) Sodium. As you can see, sodium is the most abundant positive electrolyte (or cation) in the extracellular fluid and is also present in intracellular fluid. The main function of sodium is in maintaining normal osmotic pressure.

(2) Chloride. Chloride is the most abundant negative electrolyte (or anion) in extracellular fluid and is present in intracellular fluid as well. Chloride is essential to maintain normal osmotic pressure and is found in the stomach fluid.

(3) Potassium. Potassium is the most abundant electrolyte in the intracellular fluid. Potassium is also required for osmotic pressure but has other vital functions. Potassium is required to convert dextrose (a sugar) into body energy and is required as an aid in transmitting nerve impulses within the heart.

(4) Bicarbonate. Bicarbonate helps to maintain the acid-base balance within the body (see paragraph 2-6).

(5) Phosphate. Phosphate is required for the formation of bones, teeth, and body enzymes (see paragraph 2-10 for a discussion of enzymes).

(6) Magnesium. Magnesium is essential for the formation of enzymes within the body.

(7) Calcium. Calcium is essential for the formation of bones and teeth. Calcium is needed to help in blood clotting and in maintaining the rhythm of the heart beat.

d. If a liter of body fluid is lost from extracellular fluids, all the electrolytes must be replaced along with the water. If a liter of fluid is lost by a severe case of diarrhea, the electrolytes would be of a different type and amount than those from the extracellular fluid. Therefore, both the source of the lost fluid and the amount must be considered when giving replacement fluids.

2-6. ACID-BASE BALANCE

The body's internal liquid environment is comprised of the body's fluids and the blood. For proper body functions to continue normally, this internal environment must be kept constant (homeostasis) and within a very narrow limit. The acid-base balance of the blood is maintained by the chemical balance between the cations and the anions, which must be there in a very delicate balance. The cations are sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{+2}) and magnesium (Mg^{+2}). The anions are chloride (Cl^{-}), bicarbonate (HCO_3^{-}), phosphate (PO_4^{-3}), and sulfate (SO_4^{-2}). The acid-base balance is normally expressed as the "pH." This expression is a relationship of the hydrogen ion

(acid) concentration in the blood (or in the body) and an arbitrary number. The balancing part (base or alkaline) is a hydroxy group (OH^-). The normal range of the blood pH is 7.35 to 7.45. There is a daily variation caused by production of acids by exercise and metabolism of food. In the terminal stages of some diseases, pH can vary from a low of 6.8 to a high of 7.8. The concept of pH may be easier to understand by comparing the acid (hydrogen) and base (hydroxl) factors to pure water, which is neutral (neither acid nor base). The body is always slightly alkaline. The body's acid-base balance is effectively maintained under normal circumstances by the various buffer processes which neutralize strong acids or strong bases (alkalines) using the body's various buffer systems (chemical, organic, and so forth) to help excrete excess body system products. Figure 2-3 shows the narrow range of the body's pH.

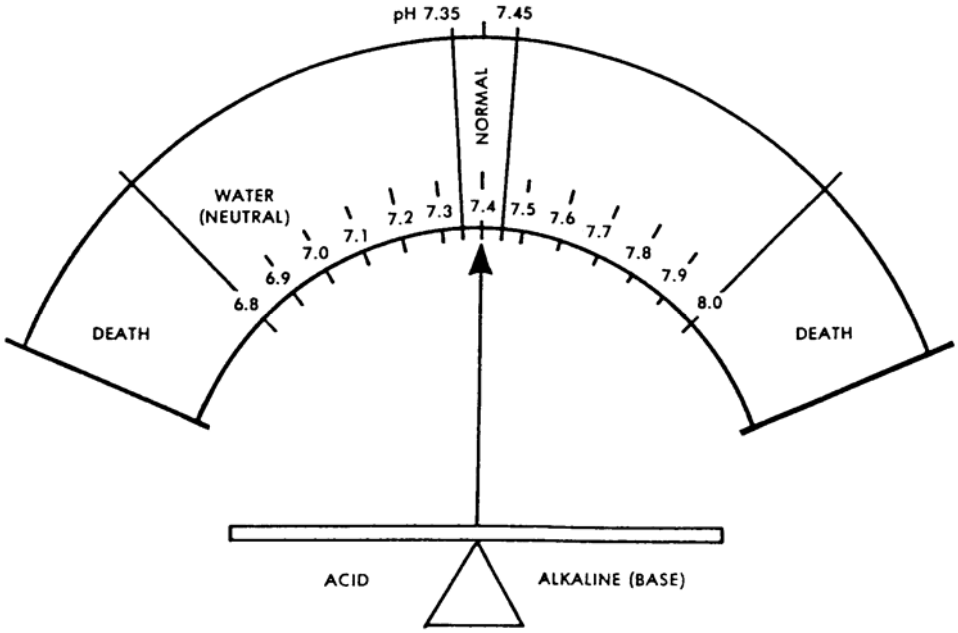

Figure 2-3. Acid-base balance.

2-7. NATURE OF SOLUTIONS

There are three movement directions possible following the introduction of injectable solutions into the body. These movement directions are governed by the nature of the solution with regard to body fluids. The fluids are called hypotonic, hypertonic, and isotonic.

a. **Hypotonic Solutions.** A hypotonic solution is one that has less tonicity than the fluid within the body's cells. This type of fluid is absorbed into the body's cells by moving across the cell's membrane and into the cell. If too much hypotonic solution is added, there is always the danger that the cells could burst or at least become irritated. Examples of hypotonic solutions are 0.45 percent sodium chloride solution and sterile water. This movement is shown in figure 2-4.

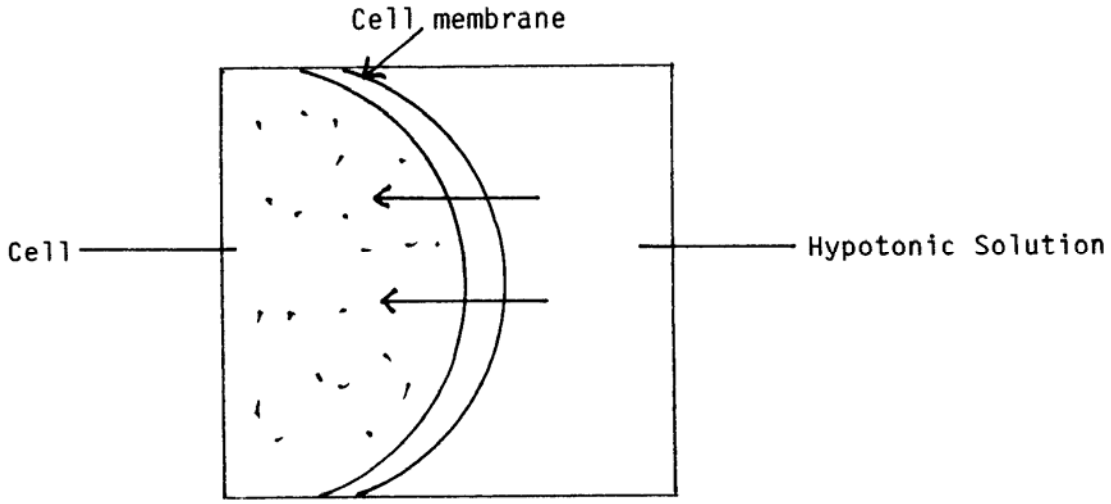

Figure 2-4. Hypotonic solution.

b. **Hypertonic Solutions.** A hypertonic solution is one that has greater tonicity than the fluid within the body's cells. When this type of fluid is injected, it causes the cells to lose fluid into the surrounding spaces. If too much hypertonic solution is injected, the cells will shrink and shrivel. The cells become irritated, and this will probably cause pain at the site of administration. Examples of hypertonic solutions are hyperalimentation solutions and 10 percent dextrose solution. This movement is shown in figure 2-5.

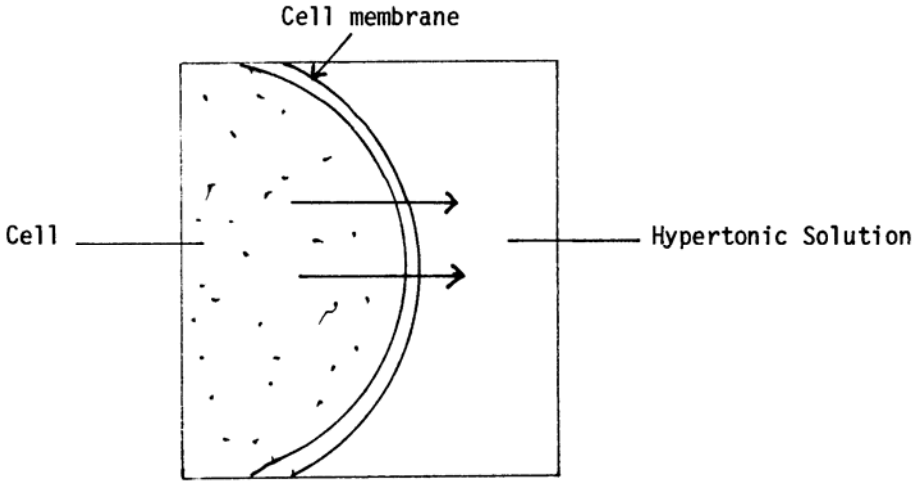

Figure 2-5. Hypertonic solution.

c. **Isotonic Solutions.** An isotonic solution has the same tonicity as that of body fluids. When this type of fluid is injected, fluids travel equally in both directions. Injection of an isotonic fluid causes no cell irritation to occur. Examples of isotonic fluids are 0.9 percent sodium chloride solution and lactated Ringer's solution. This movement is shown in figure 2-6.

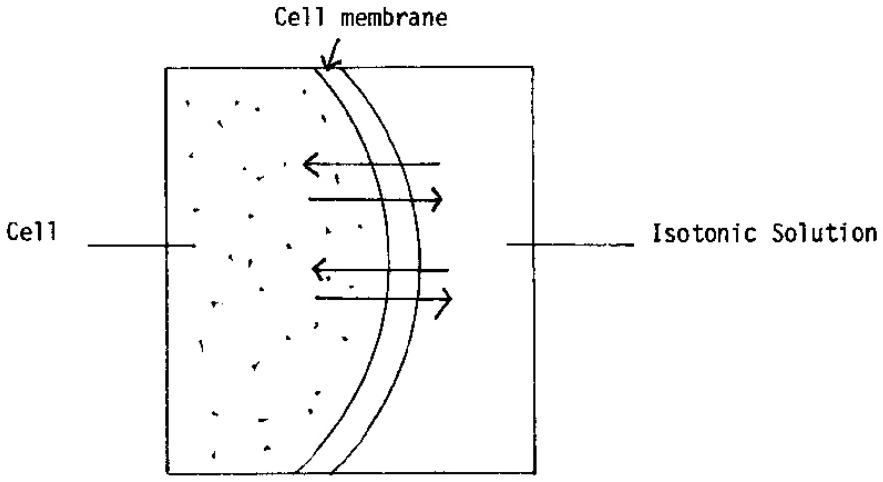

Figure 2-6. Isotonic solution.

2-8. DIFFUSION AND OSMOSIS

Even though the predominate movement of hypotonic solutions and hypertonic solutions is in one direction, there is always a weak movement in the opposite direction. This weak movement is caused by diffusion. This process is in contrast to osmosis, which is a directional movement.

a. **Diffusion.** When a solute is added to a fluid, the molecules will begin immediately to spread throughout the fluid. This process is diffusion. The movement is random. It is the nature of molecules to move constantly in a fluid. Even though no special effort (like stirring) is made to mix the solution, the solute will be evenly distributed within a period. An illustration of diffusion is to add ice cubes to a warm liquid. Without stirring, the cold molecules will distribute themselves among the warmer ones. This will create a liquid of uniform temperature. The diffusion process is not limited by the presence of a semi-permeable membrane as long as the molecules are small enough to travel through the membrane. Cell walls are semi-permeable membranes.

b. **Osmosis.** The process of osmosis is unidirectional across a semi-permeable membrane. When the molecules of a solute are too large to travel through the membrane wall, they will remain on one side. When a solvent is added to the other side of the membrane, the molecules of the solvent will travel through the membrane to the side with the greater concentration of the solute. This is the principle by which the hypotonic and hypertonic solutions move fluid across the cell membranes.

2-9. CRYSTALLOID AND COLLOID SOLUTIONS

The nature of injectable crystalloid and colloid solutions determines their ability to be absorbed by the cells or to remain in the circulatory system.

a. **Crystalloid Solutions.** Crystalloid solutions contain small molecules that pass freely through cell membranes and vascular system walls. These solutions are useful as fluid expanders and are stored at room temperature. The crystalloid solutions are a useful source for electrolytes and a temporary source of fluid volume. They flow out of the vascular system rather quickly. Lactated Ringer's is an example of a crystalloid solution.

b. **Colloid Solutions.** The colloid solution contains molecules that are frequently very complex and much larger than those in the crystalloid solutions. A solution that contains protein is colloidal. The colloidal solutions are needed when a solution is required to remain in the vascular system. Colloid solutions generally require refrigeration and can be stored for a limited period. Whole human blood U.S.P. and Hetastarch are examples of colloid solutions.

2-10. NORMAL FLUID LOSS

As mentioned earlier, there are four ways the normal healthy body loses fluids daily. People are generally unaware of the loss of fluids since the body does an excellent job of replacing the lost amounts of fluid and electrolytes. It is only when there is a severe loss during illness or injury that the body has difficulty replacing these losses.

a. **Perspiration.** Perspiration is a constant route for fluid loss. About 650 milliliters of perspiration are lost during a normal day by a healthy person. Along with water, a liter of perspiration has about 45 mEq of sodium, 4.5 mEq of potassium and 57.5 mEq of chloride. A normal person only becomes aware of the perspiration loss during very strenuous exercise or when the day is very hot. As a general rule, where sodium goes, water follows. That is why there is always sodium on the skin following heavy perspiration.

b. **Respiration.** Respiration occurs around-the-clock, but most people are not aware that they are exhaling fluid in the form of water vapor every time they breathe. We become aware of the vapor loss during cold weather when the vapor can be seen as it is exposed to low temperatures. About 450 milliliters of fluid are lost during a twenty-four hour period by respiration.

c. **Feces.** A small amount of fluid is normally contained in the feces. About 100 milliliters of fluid are lost in this manner during a day.

d. **Urine.** Urination accounts for the greatest fluid loss daily. About 1300 milliliters of urine are excreted by the normal person each day.

e. **Total.** If these four loss routes are totaled, we find that about 2500 milliliters of fluid are lost and must be replaced daily. See figure 2-7 for a summary.

Perspiration	650 ml
Feces	100 ml
Respiration	450 ml
Urination	1300 ml
	2500 ml daily

Figure 2-7. Summary chart for normal fluid loss.

2-11. ABNORMAL FLUID LOSS

There are seven means of abnormal fluid loss from the body, and these are generally quite apparent to the individual. Vomiting and diarrhea are the most frequent and obvious.

a. **Vomiting.** A person who experiences severe vomiting not only loses the fluids taken orally, he also loses the gastric fluids (or juices) that are secreted into the stomach. These juices are rich in electrolytes. For example, a liter of gastric juice contains about 50 mEq of bicarbonate.

b. **Diarrhea.** Diarrhea (loose, watery stools) frequently accompanies vomiting when people have "bugs" or the "flu." Diarrhea is not only very uncomfortable and unpleasant, it accounts for a large loss of body fluids. A loss of electrolytes (sodium, potassium, chloride and others) is accompanied by the digested nutrients present in the diarrhea that is not absorbed by the body. For this reason, a severe bout of diarrhea is followed by general weakness.

c. **Severe Perspiration.** Severe perspiration that follows strenuous exercise in a hot environment can cause loss of electrolytes as well as heavy loss of fluid. Heat injuries can result.

d. **Severe Burns.** In very severe or widespread burns, the loss of protection by the skin allows body fluids to seep from the burned skin. This is a very serious effect of burns. The fluid and electrolytes must be replaced. Fluids and electrolytes can seep from the burns as fast as or faster than replacement fluids are administered.

e. **Gastric Suction.** Gastric suction of the stomach produces an effect similar to severe vomiting. Before long, the patient will lose a tremendous amount of electrolytes along with the fluids.

f. **Bleeding.** Bleeding of any amount produces loss of plasma, red blood cells, and other dissolved substances. The effect of the loss becomes greater as the amount of bleeding increases.

g. **Diuretic Drugs.** A person who is being treated with thiazide diuretics also loses fluids and electrolytes (primarily potassium). In such cases, potassium must be given to the patient to prevent potassium deficiencies.

2-12. REPLACING ABNORMAL FLUID LOSS

When fluid and electrolyte loss becomes abnormal, the medical specialist, the physician assistant, or the physician has two means of correcting the fluid and electrolyte balance--oral (by mouth) and intravenous.

a. **Oral Route.** The safest route is oral. For example, a person on thiazide diuretics may be given orange juice or tablets to replace the potassium needed. This is the preferred route since the patient is able to move freely and the psychological problems of intravenous administration are not present.

b. **Intravenous Route.** The intravenous route makes it possible to control the volume of fluid and the numbers of electrolytes to be given. Infection can be caused by a contaminated intravenous solution, administration set, or administration site. This will complicate the recovery of an already ill or injured patient. Another consideration is the total volume of fluid to be administered to the patient over a given time period. Generally, an adult patient should not receive more than four liters (4,000 milliliters) of intravenous fluid over a 24-hour period. A careful record must be kept of the volume of fluid administered since this must be taken into account when calculating a patient's fluid intake and output. The renal condition of the patient also affects the volume of intravenous solution to be administered. When the patient has impaired kidney function, you must be very careful not to overload the patient's system.

2-13. ENZYMES

An enzyme is a complex biological catalyst. Most reactions, which are aided by catalysts in the body, would take place without the enzyme, but too slowly to support life. Enzymes speed up chemical reactions during which complex substances are broken down into simple substances. The enzymes also speed the assembly of simple substances into complex substances. The enzyme is a protein that is not consumed or used up during its action as a catalyst. In the presence of an enzyme, a reaction uses up less energy for its completion. Most enzymes have the suffix "ase" in their name. This suffix is combined with the chemical name of the substance that uses the enzyme as a catalyst. Enzymes that split starch (amylum) are called "amylase" and those that react with fat (lipid) are called "lipase." Most others are named in a similar manner.

2-14. HORMONES

Hormones are substances that are secreted by a group of glands in the body. This collection of glands is called the endocrine system. The hormones are carried by the blood to places in the body where they regulate the functions of their "target" organs. These hormones tell the organs when to operate and regulate their operation rate. The hormones coordinate body activities, control growth and development, and maintain homeostasis. When the supplying glands produce too few hormones (or stop producing), the body functions are always affected. An example of this is the insulin produced by a part of the pancreas. When the production of this hormone is insufficient, the body develops the disease we call "diabetes mellitus," an inability to properly oxidize carbohydrates.

Continue with Exercises

EXERCISES, LESSON 2

INSTRUCTIONS: Answer the following exercises by marking the lettered response that best answers the exercise, by completing the incomplete statement, or by writing the answer in the space provided at the end of the exercise.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. As man grows from infancy to adulthood, the proportion of water to his total weight:

   a. Grows greater.

   b. Decreases.

   c. Remains unchanged.

2. Which of the following routes of fluid output from the body is most subject to fluctuation?

   a. Lungs.

   b. Intestines.

   c. Skin.

   d. Kidneys.

3. The body fluid that transports food within the cells is:

   a. Intravascular.

   b. Intracellular.

   c. Extracellular.

4. The uses of body water:

    a. Are limited by its body location.

    b. Are limited by capillary tissues.

    c. Change constantly, from one use to another.

    d. Depend on the person's ethnic origin.

5. Electrolytes are substances that are:

    a. Catalysts.

    b. Organ regulators.

    c. Never lost from the body.

    d. Found in body fluids.

6. Because of their ion state, electrolytes can:

    a. Combine to form a compound.

    b. Change from cation to anion.

    c. Carry oxygen.

    d. Lose their strength.

7. The most abundant electrolyte in intracellular fluid is:

    a. Potassium.

    b. Sodium.

    c. Chloride.

    d. Magnesium.

8. The two prime considerations when ordering replacement electrolytes are:

   _____

   _____

9. The acid-base balance of the blood refers to:

   a. The person's ability to walk without falling.

   b. The amount of alcohol in the blood.

   c. The amounts of alkaline and acid in the blood.

   d. The tendency of the blood to form thrombosus.

10. Intravenous injection of an isotonic solution causes the body's cells to:

    a. Shrink.

    b. Expand.

    c. Remain the same.

    d. Depend on the electrolytes in the solution.

11. The process that causes a solvent to move across a semi-permeable membrane from a location where a solute is less concentrated to a location where the solute is more concentrated is called:

    a. Diffusion.

    b. Random.

    c. Hypertonics.

    d. Osmosis.

12. Which of the following statements is NOT true of crystalloid solutions?

    a. Crystalloid solutions are stored at room temperature.

    b. Crystalloid solutions contain large molecules.

    c. Crystalloid solutions are a source of electrolytes.

    d. Crystalloid solutions sometimes function as a temporary source of fluid volume.

13. Loss of water vapor through respirations is usually apparent to a normal person:

    a. At all times.

    b. Never.

    c. On a hot day.

    d. On a cold day.

14. Fluid loss is generally quite apparent to the person, if it is caused by:

    a. Normal perspiration.

    b. Feces.

    c. Respiration.

    d. Abnormal means.

15. Psychological problems are not as apparent if a person's electrolyte balance can be restored by:

    a. Intravenous infusion.

    b. Exercise.

    c. A bland diet.

    d. The oral route.

16. An enzyme is a catalyst because it:

_____

_____

17. Hormones are generated by a group of glands called:

    a. Endogenous.

    b. Hemostasis.

    c. Endocrine.

    d. Insulin.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 2

1. b (para 2-2)
2. d (para 2-3)
3. b (para 2-4a)
4. c (para 2-4c)
5. d (para 2-5)
6. a (para 2-5)
7. a (para 2-5b)
8. Source of the lost fluid
   Amount of fluid lost (para 2-5d)
9. c (para 2-6)
10. c (para 2-7c)
11. d (para 2-8b)
12. b (para 2-9a)
13. d (para 2-10b)
14. d (para 2-11)
15. d (para 2-12a)
16. It speeds up chemical reactions without being consumed or used up. (para 2-13)
17. c (para 2-14)

End of Lesson 2

LESSON ASSIGNMENT

LESSON 3	Intravenous Preparations and Methods for Administration.
LESSON ASSIGNMENT	Paragraphs 3-1 through 3-29.
LESSON OBJECTIVES	After completing this lesson, you should be able to:

3-1. Identify the two major types of intravenous solutions and examples/uses of each.

3-2. Identify the requirements and precautions when using intravenous therapy.

3-3. Identify the rules/requirements for venipuncture site selection.

3-4. Identify the principles that guide the use of intravenous therapy.

3-5. Identify the complications; their signs and symptoms; and the precautionary measures for intravenous therapy.

3-6. Given the required information, calculate the drip rate for an intravenous infusion.

3-7. Identify the type of products used for transfusion, examples of each type of product and their uses.

3-8. Identify the sites used for transfusion venipuncture and the usual transfusion rate.

3-9. Identify the possible adverse reactions to transfusions and their signs and symptoms.

3-10. Identify the general principles governing transfusions.

3-11. Identify examples of the common types of blood tests, their indications and their normal values.

3-12. Identify the steps for the venipuncture procedure and for discontinuing an intravenous infusion.

3-13. Identify the kinds of intravenous systems in use and the parts of the intravenous apparatus.

3-14. Identify special considerations for transfusions.

3-15. Identify the reasons for using a venous cutdown procedure.

3-16. Identify the equipment and supplies needed for the venous cutdown and the sites usually selected.

3-17. Identify the steps of procedure for the venous cutdown.

SUGGESTION

After completing the assignment, complete the exercises of this lesson. These exercises will help you to achieve the lesson objectives.

LESSON 3

INTRAVENOUS PREPARATIONS AND METHODS FOR ADMINISTRATION

Section I. INFUSIONS

3-1. INTRODUCTION

Ideally, a person gets the fluids and electrolytes needed to live by the oral route. This route has certain built-in safeguards against bacterial invasion. When the intravenous route of administration must be used, the material being given is injected directly into the circulatory system through the veins. Although, this route is certainly effective in terms of getting the fluid into the patient, the intravenous route is not completely safe. Complications (that is, infection) can happen. In the case of infection, the fluid being administered, the intravenous administration set (the equipment between the bottle or the bag and the patient), and the techniques used to start the fluid administration are possibilities for bacterial contamination. The intravenous administration of fluids is to be taken seriously.

3-2. INTRAVENOUS PREPARATIONS

You may have seen intravenous solutions being administered to a patient. The bottle or bag connected to the patient by a plastic tube means life to many patients.

a. **Intravenous Solutions.** Intravenous solutions are products that meet certain rigid requirements and are supplied ready for use by manufacturers. Examples of such intravenous solutions are five percent dextrose, 0.9 percent sodium chloride, and lactated Ringer's. These solutions are ready for use as soon as they arrive from the manufacturer. You will see the lactated Ringer’s and the 0.9 percent sodium chloride used as "to keep open" (TKO) solutions. They serve as a ready and rapid way by which drugs could be given to the patient should the patient go into shock. These solutions serve as a "base" for the admixtures.

b. **Intravenous Admixtures.** Intravenous admixtures are intravenous solutions to which have been added one or more drugs. For example, it is common for a patient to be administered a liter of five percent dextrose which has 20 mEq of potassium chloride added to it. Thus, the patient received fluid, nutrients (dextrose), and electrolytes (potassium and chloride). Typically, patients receive much more complicated intravenous admixtures. These intravenous admixtures are usually prepared in the Pharmacy Sterile Products Section by specially trained personnel who use aseptic techniques. At times, it may be necessary for the physician or the person administering the infusion to add one or more drugs after the solution is already in place. This is done only on the physicians order.

3-3. CATEGORIES OF INTRAVENOUS FLUIDS AND THEIR USES

Many patients on the battlefield or in hospitals receive intravenous fluid therapy. They receive intravenous fluid therapy for many different reasons. All solutions received aren't alike. Many patients have intravenous solutions tailored to meet their specific fluid, nutritional, and electrolyte needs, especially if they require long term intravenous therapy.

3-4. HYDRATING SOLUTIONS

a. **Use.** Hydrating solutions are used to provide the patient with required fluid that is, water). The volume of preparation administered depends on the fluid needs of the patient.

b. **Examples.** Below are some examples of preparations commonly used as hydrating solutions:

(1) Five percent dextrose solution. Five percent dextrose solution (D5W) consists of dextrose and water. One liter of the five percent dextrose contains approximately 170 calories. This solution contains no appreciable electrolytes. Therefore, electrolytes are sometimes added to the five percent dextrose solution (for example: Fifteen mEq KCL in one liter of D5W). The five percent dextrose solution is used to provide fluid replacement and energy. D5W is not commonly used in the level 1 treatment environment.

NOTE: Dextrose solution is available in several concentrations.

(2) Nine-tenths percent sodium chloride solution (normal saline). This product is a solution of sodium and water. Each 100 milliliters of solution contains 0.9 gram of sodium chloride. Nine-tenths percent Sodium chloride solution contains 154 milliequivalents of sodium and 154 milliequivalents of chloride in each 1,000 milliliters of solution. This product is used to provide fluid replacement and to replace moderate losses of the sodium ion (Na^+). Normal saline is often used in trauma patients as a volume expander before blood products are available. However, colloid solutions are preferred for volume replacement in trauma patients on the battlefield.

NOTE: Sodium chloride solutions are also available in other concentrations. For example, 0.45 percent sodium chloride solution is commonly seen.

(3) Five percent dextrose solution in 0.9 percent sodium chloride solution. This product has in each 100 milliliters, five grams of dextrose and 0.9 grams of sodium chloride. Not only does this product provide a source of fluid, it also serves as a source of both energy (170 calorie/liter) and sodium. This product is used in fluid replacement, in the replacement of moderate losses of sodium, and as a source of energy.

NOTE: Various combinations of dextrose and sodium chloride are available.

3-5. ELECTROLYTE REPLACEMENT SOLUTIONS

a. **Use.** Electrolyte replacement solutions provide both electrolytes (like sodium, potassium, and so forth) and fluid to the patient. Special electrolyte replacement solutions can be prepared in order to meet the needs of particular patients.

b. **Examples of Electrolyte Replacement Solutions.** Below are two of the solutions commonly used to replace electrolytes.

(1) Lactated Ringer's solution (LR, Ringer's lactate, RL, Hartmann's solution). This product is a solution of electrolytes in water. This product contains sodium, potassium, calcium, chloride, and lactate ions. The lactate ion in the product has an alkalizing effect. The lactate ion is metabolized in the liver to glycogen and ends up as carbon dioxide and water. Lactated Ringer's solution is used as a fluid replacement and as an electrolyte replacement. Lactated Ringer's is the preferred solution for heat injuries.

(2) Lactated Ringer's solution with five percent dextrose. This product is a combination of lactated Ringer's solution and five percent dextrose (D5RL) solution. The dextrose supplies 170 calories per 1,000 milliliters of solution. Lactated Ringer's solution with five percent dextrose is used as a fluid replacement, electrolyte replacement, and as a source of energy.

NOTE: Other combination products are available.

3-6. NUTRIENT SOLUTIONS (HYPERALIMENTATION PRODUCTS)

These products provide total parenteral nutrition for those patients who cannot, should not, or will not ingest the nutrients they need to live. It should be noted that a hyperalimentation solution can supply all the patient's nutritional needs by administration through the circulatory system. However, these solutions are quite expensive and, because of their nutrient content, are highly susceptible to bacterial growth. Most of the solutions contain high concentrations of carbohydrates (for example, dextrose). Because of this high concentration, the solutions must be administered through a large-bore vein. Just placing the needle or catheter into such a large-bore vein is a surgical procedure in itself. The hyperalimentation solution is prepared in the Pharmacy Sterile Products Section by a specially trained person. You must be very careful to prevent bacterial contamination. The preparation of the product itself is quite a job because the preparer must add ingredients in a certain sequence. Many of the components of a hyperalimentation solution are incompatible in certain concentrations. The components of most hyperalimentation solutions are water, dextrose, amino acids, electrolytes, and vitamins. One product, Intralipid^{R}, is an oil in water emulsion. Intralipid^{R} is one hyperalimentation product that can be administered through a small-bore vein such as those found in the arm.

3-7. REQUIREMENTS FOR INTRAVENOUS SOLUTIONS/INTRAVENOUS ADMIXTURES

Any solution administered through a patient's veins must be:

a. **Sterile.** Sterile means that no living microorganisms are present in the solution.

b. **Pyrogen-Free.** Pyrogens are substances that produce fever when injected into the circulatory system.

c. **Free from Visible Particulate Matter.** Visible particles in an intravenous preparation mean that the product should be discarded. These particles could have been present in the solution when it arrived in the pharmacy or they may have been accidentally added to the solution when other substances were added. Regardless of origin, these visible particles, if intravenously administered, could cause a blockage in the patient's circulatory system. Filters with very small pores are available which can remove these visible particles as the product is being administered. Remember, the origin of the particles is unknown-it is possible that some particles could be undissolved drug. Removing the drug particles would be good, but if the filtered particles are undissolved drug, by removing them you may be lowering the amount of drug in the solution.

3-8. PRECAUTIONS FOR USING FLUID THERAPY

You will likely be in a position to administer or supervise administration of fluid therapy. Some precautions will be beyond your control, but most will be your responsibility. Carefully watch for the pitfalls shown below, to make sure that the intravenous infusion does the patient more good than harm.

a. **Contamination.** A solution intravenously administered to a patient must be free from living microorganisms. You have a responsibility for using the aseptic technique. When there is doubt about the sterility of the admixture (or intravenous solution), the product should be discarded. Microorganisms are present in the environment of the hospital room. They are on the hands of the person who will start (that is, begin the administration) the intravenous product. Therefore, this person is responsible for using care and aseptic technique to make the venipuncture.

b. **Irritating Drugs.** The veins are very sensitive. Therefore, any intravenous product which has an extreme pH or which is very concentrated can irritate the veins. In some cases, the physician can decide to place the drug in another intravenous solution resulting in a pH that will not irritate the veins as much. In other cases, the site can be changed frequently to allow the part of the vein just used to recover.

c. **Particulate Matter**. Hold a bottle or bag of intravenous solution up in front of a light. See how it is sparkling clear. Actually, small particles called particulate matter are present in the solution. Standards allow extremely small particles to be present in the solution in certain concentrations. Intravenous solutions or admixtures should never be administered to a patient when the products contain visible particulate matter. A product that is cloudy might actually be cloudy because of suspended particulate matter. Even though filters are available which can filter most particulate matter from intravenous products, do not use a cloudy solution.

3-9. SITE FOR VENIPUNCTURE

a. **Selection.** Site selection for venipuncture depends on:

(1) Accessibility of the vein. A vein should be relatively easy to feel and to stabilize for venipuncture. If this task is too difficult, select another vein.

(2) General condition of the vein. If the vein is in good condition, it will easily take the venipuncture. If the vein is poor, it may collapse upon puncture.

(3) Type of fluid to be infused. If the fluid used is especially irritating, a different site will be suitable from the sites, which can be used for non-irritating fluids.

(4) Period the intravenous line is expected to be in place. Long-term intravenous therapy will often require a different site from the ones that can be used if a single bottle or bag of fluid will be used.

b. **Preferred Sites.** The following sites are generally used and preferred for use by most physicians in the clinical setting it is possible to select preferable veins for puncture. On the battlefield and keeping with the tenants of Tactical Combat Casualty Care (TC3), you should puncture a high percentage vein such as antecubital or external jugular.

(1) Distal to the antecubital area (that is, cephalic, basilic, antebrachial veins in the lower arms).

(2) Veins on the back of the hand.

(3) Veins in the lower extremities when necessary although danger of thrombophlebitis is considerably greater.

CAUTION: Select the largest vein, if possible, when injecting intravenous drugs that may produce sloughing/necrosis injury to the tissues.

(4) The leg and foot veins may be used on children because these vessels are not sclerosed.

(5) Scalp veins are used in infants.

3-10. PRINCIPLES OF INTRAVENOUS THERAPY

a. Check all bottles or bags of infusion solution for these specific requirements and discard any that show:

(1) A broken vacuum seal.

(2) Cloudiness.

(3) Precipitation (particles on the bottom of the bag or bottle).

(4) Foreign contaminants.

b. Always, use sterile equipment and wash your hands thoroughly.

c. Disinfect the patient's skin at and around the injection site. Apply antiseptic solution using friction at and around the venipuncture site.

d. For long term therapy patients.

(1) Change the injection site every 48 to 72 hours (to lessen the possibility of infection and/or irritation to the vein), or in accordance with (IAW) local standing operating procedures (SOP).

(2) Replace the tubing and solution bottle (or bag) every 24 hours (to avoid infusing a contaminated solution) or IAW local SOP.

(3) Take precautions if vein irritation or thrombophlebitis is possible.

(a) Plastic catheters are more likely to cause irritation than stainless steel needles.

(b) Use the smallest gauge needle or catheter possible.

(c) Use the shortest infusion time possible. Irritation is much more likely after 48 hours of intravenous therapy.

(d) Veins of the lower extremities (in adults) are more likely to develop phlebitis (and quicker) than those of the upper extremities.

(e) Do not irrigate a stopped infusion. You may dislodge an obstructive clot and endanger the patient's life.

(f) You are less likely to irritate the large veins of the central venous system than the smaller peripheral veins.

(g) Strict attention to aseptic techniques is required at all times to prevent sepsis.

3-11. COMPLICATIONS

The complications of intravenous therapy may be mild or life threatening, but they are always uncomfortable for the patient. Many can be prevented with proper care.

a. **Infiltration.** Infiltration (the most frequent complication) is caused by dislodgement of the needle or catheter or by puncture of the vein. This allows the fluid to collect in the surrounding tissue. Signs or symptoms include, slowing or stopping of the intravenous flow and reduced skin temperature in the venipuncture area. This is not usually serious but can be very uncomfortable for the patient. You can restart the intravenous at another site. The danger of this happening can be reduced by securely taping the intravenous line and providing arm boards for stability.

b. **Speed Shock or Circulatory Overload.** The "average" person has a blood volume of about five to six quarts. Blood is approximately ninety-one percent fluid. The body has intricate mechanisms for making up for changes in blood volume. For example, when you donate blood, some fluid from the inside of the cells and fluid surrounding the cells enters the circulating blood volume. There is a reverse flow when the blood volume is normal and intravenous fluids are administered. Unfortunately, when too much fluid and/or too much medication is administered too rapidly, circulatory overload can result. Signs and symptoms include patient complaints of pounding headache and chills, a flushed look, irregular pulse, and dyspnea.

c. **Sepsis and Pyrogenic Reactions.** Sepsis and pyrogenic reactions are usually caused by the introduction of pyrogenic organisms or their toxins into the bloodstream. In addition to these organisms, febrile reactions can be caused by various chemicals and certain types of particles. If an infection results, the reaction can be localized or systemic. A systemic reaction can occur about thirty minutes after starting the intravenous infusion. Long-term therapy patients can develop sepsis from the growth of microorganisms on the skin after a two to three day period. Signs and symptoms include an unexpected rise in temperature preceded by chills, nausea, vomiting, backache, and malaise. To reduce the possibility of developing sepsis, use aseptic techniques when starting the infusion and change the infusion site, bottle, and tubing at least every two to three days on long term intravenous therapy patients.

d. **Phlebitis.** Phlebitis is an irritation or injury to the vein. It can be caused by mechanical, chemical, or bacterial irritation. Signs and symptoms include redness, pain, and swelling at the infusion site and patient complaints of fatigue together with fever and a rapid pulse. If signs appear, change the needle to another site and apply warm moist compresses to relieve discomfort and aid healing. Do not rub or massage the affected area. You could cause thrombus or emboli and add to the vein damage. A thrombus is a clot that is formed in the blood vessels. A thrombus is usually a further complication of phlebitis. A clot formed in the vessels can produce damage to tissue below the stoppage.

e. **Air Embolism.** An air embolism is a very serious intravenous therapy complication. It can occur when a sizeable amount of air gets into the circulatory system through the intravenous administration set. It can block a vessel so that tissues are unable to get oxygen. Nutrients and waste products cannot be removed. The air bubble can cut off cardiac, cerebral, or pulmonary circulation. Symptoms include a fall in blood pressure, tachycardia (rapid pulse), and loss of consciousness. If a patient has these symptoms, take his vital signs, place patient on his left lateral side, administer oxygen, and get immediate medical help. Air embolism can be prevented by removing all air (bleeding) from intravenous lines, using venipuncture sites below heart level, and never allowing an intravenous line to run dry before disconnecting or adding another bottle. The larger the embolus, the greater the danger. Death could result.

f. **Solution's Incompatibility.** The signs of incompatibility will differ according to the solution or drug being administered. The effects can vary from neutralizing the effects of a drug to causing circulatory collapse. Some solutions, such as over 10 percent dextrose or potassium chloride, are very irritating in concentrated doses. Sterile water, saline, or special dilutants are required for certain drugs and substitutions should not be made. Incompatible drugs frequently form a precipitate and cause fever, nausea, vomiting, and intense itching.

3-12. CALCULATING THE INTRAVENOUS DRIP RATE

In order to infuse a solution ordered by the physician, it is necessary to calculate the infusion rate. A drip rate calculation may be desired for maintenance of trauma patients that you may not be able to immediately evacuate. During the care under fire phase of tactical care the appropriate hypovolemic fluid protocols should be followed for the benefit of your patient and triage of your available supplies.

a. The physician who ordered the infusion for the patient will give you the following information:

(1) The type or kind of fluid to be infused.

(2) The amount of fluid to use.

(3) The time period over which the total amount of fluid is to be infused.

b. From the infusion set, you will learn how many drops per ml the set is capable of providing. You must determine how many drops per minute are required in order to set this delivery rate on the infusion set. The formula for determining the drip rate is given below.

$$\text{Flow rate in drops per minute} = \frac{\text{Volume (in ml) to be infused} \times \text{Drops per ml delivered by the set you are using}}{\text{Infusion time in minutes}}$$

3-13. EXPLANATION OF DRIP RATE FORMULA

The above formula can be used by following these steps.

a. Multiply the number of ml to be infused (ordered by the physician) by the drops per ml delivered by the set you are using (shown on the infusion set).

b. Multiply the hours of infusion time (ordered by the physician) by 60 minutes.

c. Divide the answer in step number one by the answer in step number two. This answer will be the flow rate.

3-14. EXAMPLE OF A DRIP RATE CALCULATION

Let us use an example to illustrate this process. The physician has ordered you to infuse 2000 ml of normal saline. The fluid is to be infused over eight hours. Your infusion set delivers 15 drops per milliliter. How many drops per minute should be administered?

a. Multiply 2000 ml by 15 drops per ml. Answer: 30,000 drops.

b. Multiply 8 hours by 60 minutes. Answer: 480 minutes.

c. Divide 30,000 by 480. Answer: 62 drops per minute.

Section II. TRANSFUSIONS

3-15. INTRODUCTION

Transfusions of blood or blood products are normally initiated at the direction of the physician during surgery. These transfusions differ from the infusion of other fluids in many ways. The products used are generally prepared in a laboratory. Many products need to be matched to the patient by using laboratory analysis. The rate of transfusion is often slower, and a greater variety of complications is possible. The venipuncture site may be different. Even the equipment differs from other administration sets. Most blood products have special refrigeration requirements to prevent spoilage. The most common reasons for transfusions are replacement of red blood cells for oxygen-carrying capacity or restoration of blood volume. Transfusion should not be initiated too hastily. Most patients in good general health can sustain a loss of about 1,000 milliliters and need replacement by colloid or crystalloid solutions infusion alone. Transfusion should be used as a last resort. It may lower the production of erythrocytes by the patient's own body. The normal red cell has a life span of about 80 to 120 days. Each unit of blood contains red blood cells of all ages between 1 and 120 days. As a unit of blood is stored, the red blood cells continue to age. A unit of blood is stored for no more than 35 days. These aged blood cells are removed from the patient's circulation by his own body within 24 hours after transfusion of the unit of blood. About 70 to 79 percent of the red blood cells survive 24 hours after transfusion and begin to age normally. Many surgeons believe that surgical blood loss can usually be replaced with packed red blood cells and saline.

3-16. PRODUCTS FOR TRANSFUSION

Sodium chloride solution (normal saline) is the only solution suitable for use in the transfusion of blood products containing red blood cells, platelets, or leukocytes. Any other solution causes adverse effects on the body and/or blood product. There are three general categories of products used for transfusion-products containing red blood cells, plasma products, and plasma expanders.

a. **Red Blood Cell Products.** Red blood cell products generally require type and cross-match laboratory procedures. Examples of these are:

(1) Whole blood (human). Whole blood is anticoagulated blood from which none of the components have been removed. Acute significant hemorrhage is the only indication for whole blood in medical patients. Traditionally, whole blood has been used to replace blood loss at surgery. This use is gradually changing to the use of packed red blood cells and a balanced saline solution.

(2) Packed red blood cells. Packed red blood cells have 75 percent of the plasma removed in the laboratory. This preparation is frequently used where the patient needs the oxygen-carrying capacity of the erythrocytes, but would not benefit from the extra fluid or the small amount of protein in the plasma. In many chronic diseases, a further expansion of the plasma volume can cause heart failure. The packed red blood cells also tend to cause less plasma transfusion reactions from donor antibodies. It is safer to use type O Negative packed red blood cells than whole blood when there is no time for cross-match.

b. **Plasma.** Plasma (or other blood fraction) products are made either from whole blood or from some other process that leaves part of the blood behind. Some examples of these are:

(1) Whole plasma. Whole plasma may be a by-product from the preparation of packed red blood cells, made from blood a few days before the expiration date on the blood unit or drawn by plasmapheresis. Plasma is used as fluid replacement caused by hemorrhage, burns, or in other situations where blood volume must be increased without replacement of blood proteins.

(2) Cryoprecipitate. To make cryoprecipitate, fresh frozen plasma (FFP) is first thawed at 4ºC until all ice is melted. Then the cold insoluble fraction of plasma protein is recovered by centrifugation. The product is used for patients with hemophilia. Cryoprecipitate can be stored for two years at -20º C (20 degrees below 0 Celsius).

(3) Platelet rich plasma. Platelet rich plasma is used in the treatment of some forms of malignancy. This product may be effective in controlling serious active bleeding, especially in surgery. Because of the short survival rate of platelets, the product has limited use. A-B-O group type match is required. No cross-match of other factors is required prior to platelet transfusion unless the platelet product contains many red blood cells. This does not apply to the platelet rich plasma since the plasma itself may carry antibodies.

c. **Plasma Expanders.** Plasma expanders are used to treat or prevent acute and severe fluid loss due to trauma or surgery. These products are usually used instead of whole blood in emergency-situations in which whole blood is not available. Below are examples of plasma expanders.

(1) Normal human serum albumin. Normal serum albumin is a part of whole blood. It is clear, moderately viscous, brownish fluid contains 25 grams of serum albumin in 100 milliliters of product. Because each gram of albumin holds approximately 18 milliliters of water, it is used as a blood volume expander in the treatment of hemorrhage or shock. In this use, the albumin draws fluid into the circulatory system from the surrounding tissues. This product has also been used as a protein replacement in cases where the level of protein in the serum is very low (for example, in nephrosis). Normal human serum albumin should not be given to dehydrated patients since it draws fluid from the body tissues. If nine-tenths percent, the product may be administered to dehydrated patients if it is necessary. Sodium chloride solution or five percent dextrose solution is administered at the same time. Fortunately, this product is very stable. Therefore, it is not necessary to keep it refrigerated in its liquid state.

(2) Plasma protein fraction (plasmanate). Plasma protein fraction is a sterile solution of stabilized human plasma proteins in nine tenths. Sodium chloride solution. Each 100 milliliters of this product contains approximately five grams of protein. This product is nearly colorless (slightly brown). Plasma protein fraction is used in the treatment of nonhemorrhagic shock (that is, shock not associated with loss of whole blood). Side effects associated with this product are uncommon, but they include increased salivation, nausea, and vomiting.

(3) Hetastarch. Balanced electrolyte solution that resembles the composition of the principal ionic constituents of normal plasma. Total dosage and rate of infusion depend on the amount of blood or plasma lost and the resultant hemoconcentration as well as age, weight, and clinical condition of the patient. Generally no more than 1L of Hextend (hetastarch in lactated Ringer's solution) should be given. Side effects include systemic overload, and it can inhibit the clotting processes.

3-17. SITE FOR VENIPUNCTURE WHEN A BLOOD PRODUCT IS USED

Blood products should be administered intravenously although other routes (intraperitoneal, intra-arterial, intraosteous are possible. A vein should be selected which will be large enough to accommodate the infusion needle but is comfortable for the patient. Veins in the antecubital fossa are probably more accessible and most widely used; however, infusion in these veins limits the patient's ability to flex the elbow during transfusion. Veins in the forearm and hand are equally suitable for infusion, although venipuncture in these areas is often more painful to the patient.

3-18. RATE OF TRANSFUSION

a. The rate of transfusion of blood products depends upon the clinical condition of the patient and the product being transfused. In most administration sets, 15 drops equal one milliliter.

b. Most patients who are not in congestive heart failure or in danger of fluid overload tolerate the transfusion of one unit of red blood cells in a 1 1/2 to 2 hour period. One unit of whole blood equals about 500 milliliters (about 450 milliliters of blood plus 60 milliliters of anticoagulant). The transfusion should be completed in less than four hours because of the dangers of bacterial growth and red blood cell hemolysis at room temperature. During the first 15 minutes, the rate of transfusion of red blood cells should be very slow, about 100 milliliters per hour. This will keep the volume of red blood cells low in case the patient has an immediate adverse reaction. Watch the patient attentively during the first five minutes and then check after fifteen minutes. At that point, the rate may be increased if the physician orders. After the transfusion, record any adverse reaction and discontinue the intravenous infusion.

3-19. ADVERSE BLOOD PRODUCT REACTIONS

Most adverse transfusion reactions are caused by leukocytes, platelets, and plasma proteins (since red blood cell antibodies have already been checked). All the care in cross-matching blood in the laboratory can be negated by administering the blood to the wrong patient. Always double-check.

a. **Immediate Effects.** An adverse effect can be either immediate or delayed. If the effect is immediate and the transfusion reaction involves more than just a reddening of the skin, the transfusion should be stopped immediately, but the intravenous line should be kept open.

(1) Congestive heart failure. Congestive heart failure that is caused by circulatory overload shows up as coughing, cyanosis, and difficulty in breathing. This is probably the most preventable adverse reaction to transfusion. If a patient is susceptible to circulatory overload, concentrated red blood cells should be transfused at no faster than one milliliter per kilogram of body weight per hour.

(2) Febrile reactions. Febrile reactions (fever), often preceded by chills, are the most common adverse transfusion reactions. These reactions are usually mild and result mainly in patient anxiety and discomfort. Rarely, there is some infiltration in the lungs, reduction in the body's white cells, shock, or death. There are variations in blood products or medications that may lessen febrile complications.

(3) Allergic reactions. Allergic reactions are usually relatively mild. Most are local skin redness, hives, and itching. These are treated with antihistamines. Flushing, nausea and vomiting, diarrhea, changes in blood pressure and anaphylaxis are severe reactions that sometimes require a specially prepared blood product. Some severe reactions can be treated by antihistamines. Others require epinephrine.

(4) Hemolytic reactions. These are often difficult to detect. Initial hemolytic reactions can be flushing, a feeling of apprehension, chest or back pain, chills, fever and nausea, or vomiting. During anesthesia, diffuse bleeding may be the only evidence. Severe reactions include excessive hemoglobin in the blood plasma, hemoglobin in the urine, abnormally low blood pressure, coagulation in the blood vessels, renal failure, and death.

(5) Bacterial contamination. This rarely occurs. When it does occur, a life-threatening reaction is likely. Signs and symptoms of bacterial contamination include the rapid onset of chills, high fever, vomiting, diarrhea, very low blood pressure, and acute renal tubular necrosis.

(6) Hypothermia. If blood is not warmed before a massive transfusion, hypothermia can cause ventricular arrhythmia and cardiac arrest.

(7) Hyperkalemia. Certain patients can react to the potassium that slowly leaks into the blood plasma during storage. The patient may exhibit neuromuscular problems such as muscular weakness and paralysis. Heartbeat may be irregular (usually slowed), and death could result from cardiac arrest.

(8) Microemboli. Transfusion of large volumes of banked blood may require filtering to remove debris accumulated from the breakdown of platelets, fibrin, and leukocytes during storage. This can lead to impaired oxygen transport ability in some patients who are administered large amounts of banked blood. The patient will exhibit breathing difficulties and pain in the extremities.

b. **Delayed Effects.** Adverse reactions can sometimes take weeks to show up. These are generally beyond the capability of the medical NCO to correct.

(1) Hemolytic. Delayed hemolytic reactions occur and usually result in extravascular removal of transfused cells from the circulation. This effect may take days or even weeks after the transfusion.

(2) Viral Hepatitis. The occasional occurrence of post-transfusion hepatitis remains a serious consequence of blood transfusion. Albumin, plasma protein fraction, and immunoglobulin preparations are regarded as safe derivatives since hepatitis virus is usually inactivated or removed during preparation.

(3) Others. Diseases such as malaria, acquired immune-deficiency syndrome (AIDS), hepatitis, and syphilis can be transmitted. Adequate donor screening is the only effective protection against these diseases presently.

3-20. GENERAL PRINCIPLES OF TRANSFUSION

Most of the rules for infusions also apply to transfusions. The rules below also apply to transfusions.

a. The venipuncture should be started before or at the same time the blood component is being obtained. This will allow the transfusion to begin immediately after the blood component has arrived and minimize the risk of improper storage.

b. The administration set should be cleared of air before venipuncture. Venipuncture can be performed with a needle attached to a syringe or attached directly to the blood administration set.

c. Red blood cells or whole blood should be administered using a needle of 18 gauge or larger. Other blood products such as platelets, cryoprecipitate, fresh frozen plasma, and albumin can be administered through smaller needles.

d. Warming of blood may be necessary if large amounts of blood are being transfused at a rapid rate.

e. Identification of the blood product at time of transfusion requires:

(1) Check the ABO group and the Rh type on the label of the blood container to be certain it agrees with the compatibility record (that portion of the patient's hospital record that shows his blood type and other pertinent information).

(2) Check the number on the label of the blood container to be certain it agrees with the compatibility record.

(3) Check the blood compatibility record for the patient's name and hospital number.

(4) Check the name and hospital number on the patient's wrist identification band against the information on the compatibility record.

(5) When possible, ask the patient to identify himself by stating his name.

NOTE: Never ask, "Are you Mr. _____?"

(6) The person who identifies that the correct blood product is being administered to the patient should then sign the compatibility record, and that record should be placed in the patient's chart at the completion of the transfusion. Do not begin the transfusion until any discrepancies in the above information are resolved.

3-21. BLOOD TESTS

The results of blood examinations are required to definitely rule out practically every disease. A physician would hesitate to declare a patient free from a disease until certain blood tests have been performed and the results of these tests can be included with the patient's health examination by other means. Even if the specific suspected disease is not expected to produce changes in the patient's hematologic (or blood picture) profile, this fact is required to support diagnosis. Blood tests are normally ordered by the physician and completed in a clinical hematology laboratory. The medical NCO should be aware of the commonly ordered tests and how some of the test results may indicate or point toward disease diagnosis. Most blood changes do point toward disease. The more common blood examinations are frequently all that are required for a patient. Their chief purpose is to indicate whether more detailed hematologic procedures are required. Listed below are some of the commonly performed tests you might expect to encounter in a clinical setting. The tests to be discussed here are the complete blood count (CBC), hematocrit, hemoglobin, sedimentation rate, partial thromboplastin time, and prothrombin time. There are many others. The selection of the test(s) will depend on the suspected disease, physician's preference, and the laboratory facilities.

a. **Complete Blood Count.** The complete blood count (CBC) includes the red blood count and the white blood cell count. These may be done either by using manual or by using automated methods.

(1) The red blood cell count (RBC) results in million RBCs per cubic millimeter in the sample. The normal values are 4.2-5.4 million RBCs per cubic millimeter for adult males and 3.6-5.0 million RBCs per cubic millimeter for adult females. To perform the test, a sample of blood is diluted with a special isotonic solution. When the sample has been mixed enough, part of the sample is put into a ruled counting chamber. Five ruled sections are counted, and the RBC is calculated.

(2) When the total leukocytes (white blood cells) are counted, no distinction is made for the type of white cell (for example, lymphocyte, monocyte, and so forth). If distinction is required, further testing must be done. The normal range for adults is 4,500-11,500 per cubic millimeter. Leukocyte counting is usually done electronically, but can be performed manually. A blood sample is mixed with required solutions, and gentian violet is added for color. A measured sample is put into a ruled counting chamber. Four marked sections are counted, and the white blood cell count (WBC) is calculated.

b. **Hematocrit (Packed Cell Volume).** The hematocrit is the volume of erythrocytes expressed as a percentage of whole blood in a sample. An anticoagulant is added to a small blood sample, and the tube is tightly capped to avoid evaporation. The sample is placed on a centrifuge and turned for five to thirty minutes (depending on the method and equipment used). The red cell column is measured in height (millimeters) against the height (in millimeters) of the whole column. The normal hematocrit for males is between 40 and 54. For females, the normal range is between 38 and 47. A value below the patient's normal or below the normal range may indicate anemia. A higher reading may indicate polycythemia.

c. **Hemoglobin.** The hemoglobin concentration in the blood bears a direct relationship to its oxygen carrying capacity. Because of the relationship, this test is performed on practically every patient, especially for suspected diseases associated with anemia. There are several ways to measure hemoglobin. The most widely used and recommended method uses cyanide compounds to convert the hemoglobin. This process will eventually result in a compound called "cyanmethemoglobin". The hemoglobin content can then be determined. The use of cyanide compounds in this process increases the danger of accidental poisoning in the laboratory. Proper ventilation and protection for the technician must be available. The normal values are 14 to 17 grams hemoglobin (per deciliter) for adult males and 12 to 16 grams hemoglobin (per deciliter) for adult females.

d. **Erythrocyte Sedimentation Rate.** The erythrocyte sedimentation measures the rate at which the red blood cells settle out of the cellular-plasma suspension. The rate is usually increased in inflammatory infections, toxemia, cell or tissue destruction, severe anemia, active tuberculosis, syphilis, acute coronary thrombosis, rheumatoid arthritis, and malignant processes. The rate is generally decreased by sickle cell anemia, polycythemia, hypofibrinogenemia, and certain drugs. The procedure is to place a measured amount of anticoagulated blood in a tube and measure the distance the erythrocytes fall within a given time interval. Normal values are 0 to 9 millimeters for adult males and 0 to 20 millimeters for adult females. This test is inconclusive. It indicates the need for further testing. In some cases, such as acute rheumatic fever or congestive heart failure, the sedimentation rate has remained within normal limits.

e. **Partial Thromboplastin Time.** The partial thromboplastin time is the most useful screening method for detecting blood coagulation disorders. This procedure tests all three stages of blood coagulation and can show abnormalities in almost all of the clotting factors. Freshly collected blood is combined with certain compounds and observed for clot formation. Using most commercially prepared and some laboratory prepared compound, the clot should form in less than 35 seconds to be considered normal.

f. **Prothrombin Time.** The prothrombin time procedure detects abnormalities in the clotting time in some stages of the clotting process. If certain amounts of thromboplastin, calcium, and citrated plasma are carefully mixed under controlled conditions, fibrin strands will normally form within seconds. The time between the addition of plasma and the formation of the fibrin web is read. Normal values are 12 to 15 seconds. The prothrombin activity of the patient's plasma has important significance in diseases of the liver, in vitamin K deficiency, and in the use of dicumarol as an anticoagulant.

Section III. INFUSION PROCEDURES

3-22. INTRODUCTION

The intravenous infusion is often started by the combat medical specialist or the medical NCO in the field during a battle situation. The following method is essentially a review of the technique that was taught during medical training. This procedure requires practice under the supervision of a trainer who is experienced in the procedure. Mastery of the following material should not be interpreted as mastery of this task. It cannot substitute for hands-on supervised training and practice.

3-23. EQUIPMENT REQUIRED FOR THE INFUSION

The equipment used for both the infusion and the transfusion have many similarities and some differences. The equipment for the infusion is normally available in the field. Usually, the transfusion setup is available where blood products are administered.

a. **Containers.** There are three types of fluid container systems in current use, the closed system, the open system, and the plastic bag (see figure 3-1).

(1) Closed system. The closed system bottle has an air vent through which medication may be added. A filter must be removed and then replaced. The sterility of the solution can be destroyed by careless handling of this filter.

(2) Open system. The open system bottle draws in added medication by vacuum, so this vacuum must be carefully maintained. The level of fluid remaining in the bottle is easily noted in both the open and closed systems.

(3) Plastic bag. The plastic bag has a port for adding the medication, but has no vacuum. Special care must be taken to be sure that the set is clamped off and medication is well mixed to prevent the patient from getting a toxic dose of the medication. It is difficult to judge the fluid remaining in the bag because it collapses as the fluid is withdrawn. Figure 3-2 shows medication being added to the three systems.

b. **Drip Chamber.** The drip chamber measures the rate of flow, as ordered by the doctor. There are several types of chambers. An example is shown in figure 3-3.

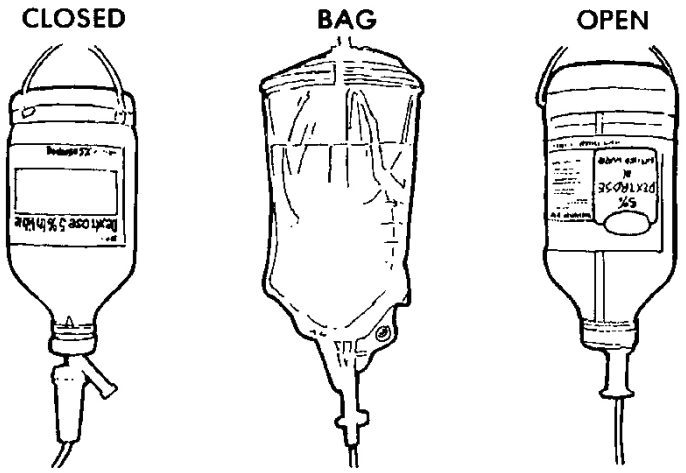

Figure 3-1. Containers for infusion solutions.

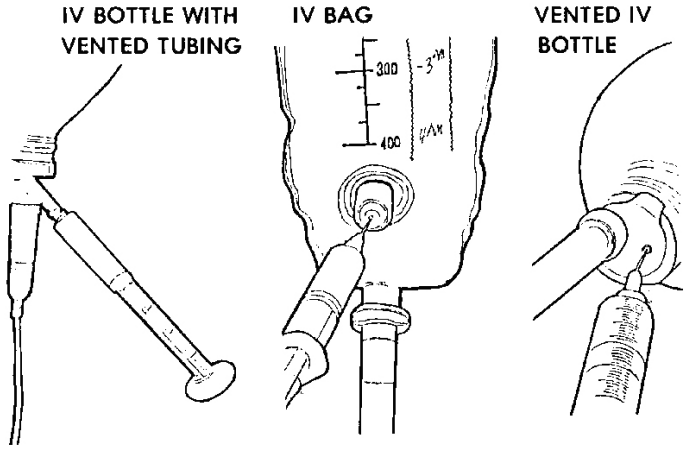

Figure 3-2. Adding medication to solutions.

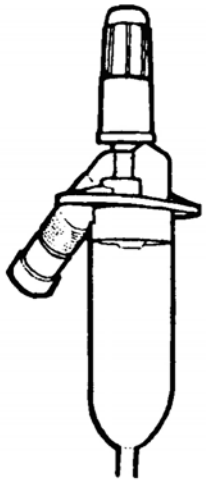

Figure 3-3. A drip chamber.

c. **Tubing.** The tubing and clamp are part of the administration set. There is enough tubing to allow an ambulatory patient to move around.

d. **Filters.** Some filters are already in the administration set and some must be attached separately. The type of filter used will depend on the solution being infused.

e. **Spikes.** Each type of system has a spike, which must be inserted into the fluid container. After this is done, the line must be cleared of all air. This is done by gradually lowering the tubing from the fluid container until the whole line is filled with fluid. All air must be forced from the tubing. Then the tubing is clamped off. Sterility must be maintained throughout the assembly process.

f. **Needle.** The size and type of needle will depend on the fluid infused and the local SOP. Sizes used are 14, 16, and 18 gauge (a lower number indicates a larger bore). A commonly used needle is the butterfly type with plastic wings. Some needles allow the catheter to be inserted with the needle while some have over-the-needle catheters. Some examples are shown in figure 3-4.

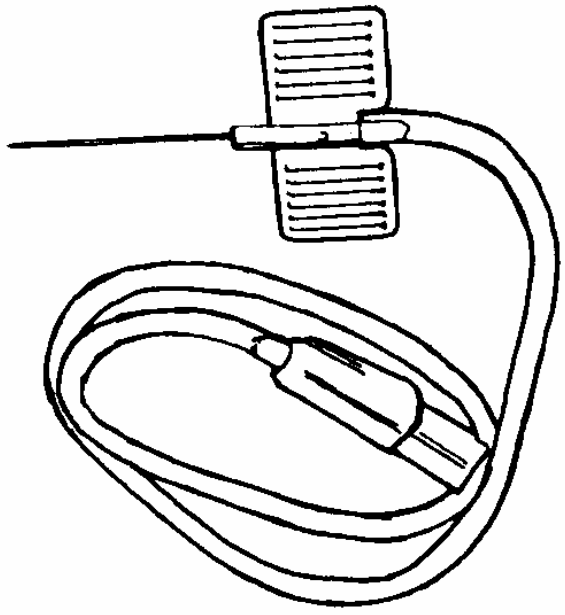

Figure 3-4. Winged-tip needle. "Butterfly" (with tubing and adaptor).

g. **Adhesive Tape.** The needle/catheter must be taped in place to prevent dislodging or vein irritation. Tape application will depend on the type of needle/catheter used.

h. **Constricting Band.** Any firm strip may be used. Examples are rubber tubing, cravats, or a blood pressure cuff. The band must remain in place no longer than two minutes.

i. **Antiseptic and 2 x 2 Gauze.** The patient's skin must be cleansed at the venipuncture site, both before and after venipuncture. Antimicrobial ointment is usually applied at the site before taping the needle/catheter in place. Figure 3-5 shows an infusion in place.

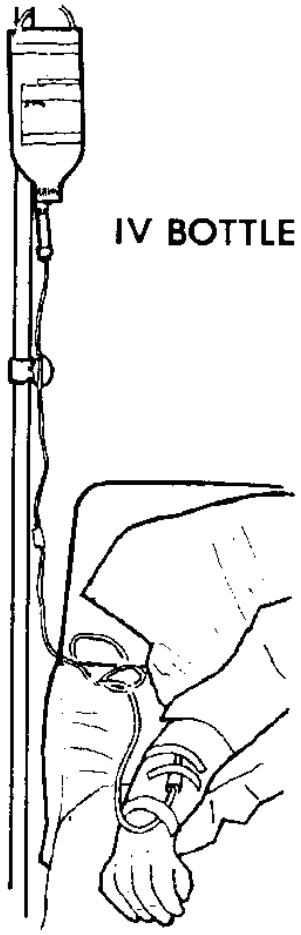

Figure 3-5. Infusion in place.

3-24. PROCEDURE FOR VENIPUNCTURE

a. Explain the procedure to the patient. If the patient is conscious and objects to the procedure for religious or other reasons, no further attempt should be made. If the patient is unconscious, consent is implied, and the venipuncture may proceed.

b. Assemble and set up the equipment. (See paragraph 3-23 for equipment).

c. Wash your hands.

d. Select an infusion site on the uninjured arm. Site should be at the most distal and accessible vein. Distal pulse should be present.

e. Apply the constricting band above the site and palpate for a fairly straight vein which lies on a hard surface. Vein should feel springy to palpation. Avoid sites near joints.

f. Cleanse the selected site and instruct the patient to clench and unclench his fist several times to improve venous distention.

g. Remove protective cover from catheter/needle unit without contaminating the needle.

h. Apply gentle pressure on the vein about one inch below the injection site and pull the skin taut.

i. Position the needle at a 20- to 30-degree angle and in the direction of the venous flow.

j. Insert needle and decrease the angle until almost parallel to skin surface. Aspirate for blood backflow or note blood in the flash chamber. If the first attempt is unsuccessful, pull the needle back slightly (but not above the flesh surface) and direct the needle point into the vein again. If this second attempt is unsuccessful, release the constricting band and withdraw the needle.

k. Remove the constricting band. Press the skin lightly over the catheter to constrict the vein and prevent excessive blood loss into the catheter. This procedure should be attempted again in another place.

l. Using your dominant hand, remove the protective cover from the needle adaptor and connect it quickly and tightly to the catheter hub.

m. Remove your other hand from the hub, release the clamp and adjust the flow. Check for infiltration.

n. Clean the area around the venipuncture and place ointment/dressing IAW local SOP. Tape the looped tubing securely to the patient's arm.

3-25. DISCONTINUE AN INTRAVENOUS INFUSION

a. **Introduction.** An infusion must be stopped if there are complications beyond the capabilities of the medical NCO. The infusion will be discontinued at the physician's order.

b. **Procedure to Discontinue.**

(1) Explain to the patient why the infusion is being discontinued and tell him what you are doing while you are working.

(2) Assemble the needed supplies-2 x 2 gauze, self-adhesive bandage, antiseptic.

(3) Turn off the solution flow.

(4) Remove all tape at the venipuncture site.

(5) Open and place a 2 x 2 gauze at the infusion site.

(6) Hold the site steady while gently removing the catheter. Do not apply pressure.

(7) Hold or instruct the patient to hold the gauze at the infusion site for 2 to 3 minutes to avoid hematoma. If infiltration is present, elevate extremity on a support.

(8) Apply a self-adhesive bandage.

(9) Record the amount left in the bag, the amount of fluid received by the patient, and the time the infusion was discontinued. Record any problems.

3-26. SPECIAL CONSIDERATIONS FOR TRANSFUSIONS

a. **Introduction.** Most of the requirements for the intravenous infusion also apply to the blood or blood component transfusion. There are some additional points that should be noted.

b. **Equipment.** The needles used are no smaller than 18 gauge (and frequently a larger gauge). A special administration set with filter(s) is required for most blood products.

c. **Typing.** Unless time and/or access to laboratory services are restricted, all patients should be typed, and the blood used should be cross-matched on all necessary factors. If the transfusion is needed immediately, type O Rh-negative packed red blood cells may be used. In this case, the patient must be checked constantly for hemolytic reaction during the transfusion.

d. **Storage.** Whole blood, with a preservative added, has a maximum allowable storage time (shelf life) of 35 days. In comparison, many of the parenteral solutions can be stored indefinitely (or at least for several years). During this storage, time the blood must be kept at 1ºC to 6ºC. This temperature is beyond the capabilities of most field refrigeration units. When a blood unit is delivered for use, it should not stand unnecessarily at room temperature. Delayed transfusion will add to the possibility of bacterial growth. If the blood unit must be kept at a field location and adequate refrigeration is not available, it should be stored in a Styrofoam container with a cloth divider covered with a bag of ice.

e. **Rejecting Donor Blood.** If a blood unit appears abnormal in any way, it should not be used. The blood unit should not be used if:

(1) The blood unit looks purple or brown.

(2) Clots are visible.

(3) There is an obvious breakdown of blood cells.

(4) There is leakage from the container.

f. **Warming of Blood.** In cases where a large amount of blood is to be transfused at one time, the blood will need to be warmed. If too much cold blood is transfused at once, the patient can go into shock caused by hypothermia. Examples of blood warming coils are shown in Figure 3-6. Use of these coils should be directed by experienced personnel.

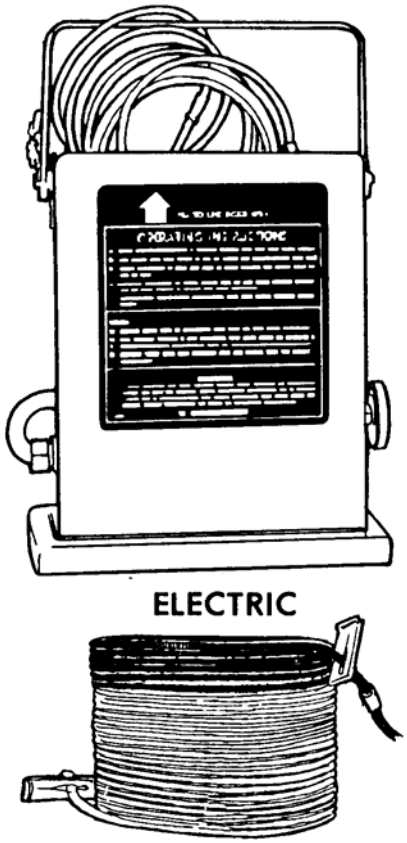

Figure 3-6. Example of warming coils.

Section IV. VENOUS CUTDOWN

3-27. INTRODUCTION

The venous cutdown is a minor surgical procedure normally done by a physician. The following information is presented for the medical NCO so that you will be acquainted with the method. You may be called upon to assist the physician in maintaining sterility of the equipment and in caring for the patient following the procedure. Venous cutdown is a sterile procedure.

3-28. REASONS FOR USING THE VENOUS CUTDOWN

If an external site for the venipuncture cannot be located, a venous cutdown can be required. This situation may occur when a patient's veins have collapsed. If the patient is in shock, very thin, or in poor physical condition, a site for venipuncture may not appear. By doing a venous cutdown, the catheter can be inserted directly into a vein, and intravenous therapy can be started.

3-29. VENOUS CUTDOWN PROCEDURE

The following is a brief discussion of the venous cutdown procedure. You will perform only those actions that the physician tells you to perform.

a. **Equipment and Supplies.** Equipment and supplies used in a venous cutdown are listed below.

(1) Sterile gloves.

(2) Scalpel handle and blades.

(3) Suture materials.

(4) Hemostats.

(5) Scissors (vascular and suture).

(6) Supplies for prepping and dressing the wound area.

(7) Intravenous setup.

(8) Sterile towels, mask.

(9) Splint, if required.

(10) Other supplies and equipment as required by physician (and available).

b. **Site.** Several sites may be chosen depending on the condition of the patient and the fluid to be infused. Some suggested sites are listed below.

(1) Basilic vein above the elbow.

(2) Basilic vein below the elbow.

(3) Saphenous vein above the ankle.

(4) Cephalic vein below the elbow.

c. **Procedure for the Cutdown.**

(1) Assemble the equipment and supplies.

(2) Wash your hands.

(3) Explain the procedure to the patient.

(4) Prepare and stabilize the site.

(5) Apply/inject a local anesthetic so the patient will not feel the incision.

(6) Make a transverse cut and dissect the tissue until the vein is visible (see figure 3-7). Using a curved hemostat, gently spread the underlying tissue to fully expose the vein.

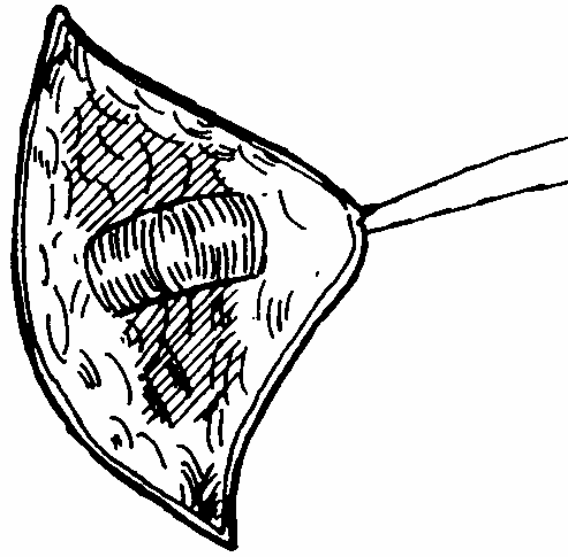

Figure 3-7. Open incision for venous cutdown.

(7) Lift the vein and put two threads of suture under it (see figure 3-8).

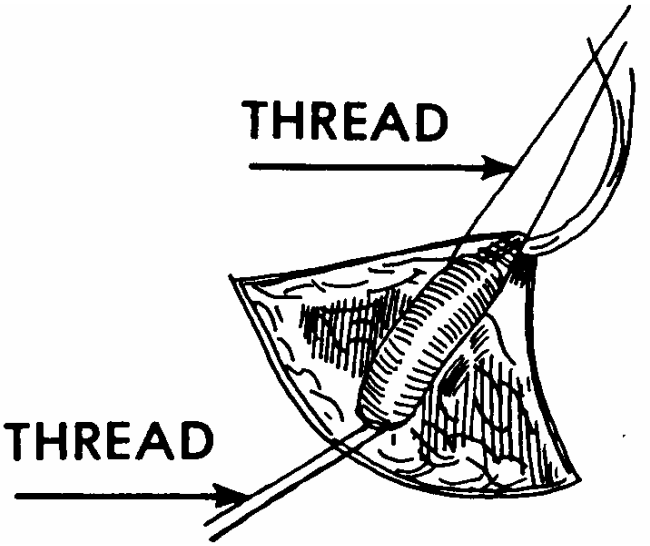

Figure 3-8. Thread under vein.

(8) Tie both threads and pull in opposite directions. Leave enough vein between the two ties to insert the catheter.

(9) Nick the vein with a scalpel (or cut with vascular scissors). (See figure 3-9.)

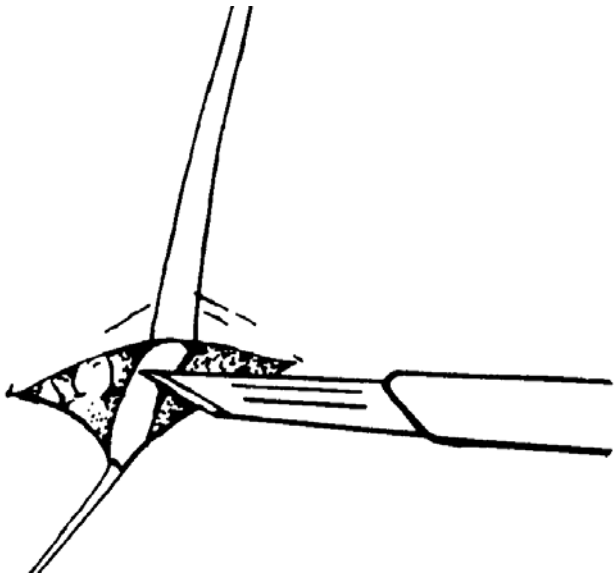

Figure 3-9. Nick vein with scalpel.

(10) Insert the proper size plastic catheter into the exposed vein (to near the catheter hub) and secure (see figure 3-10).

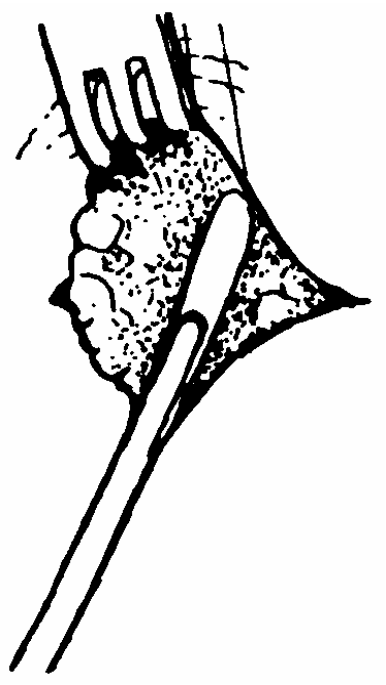

Figure 3-10. Insert catheter into vein.

(11) Attach catheter to previously prepared infusion set and close the wound.

(12) Suture the incision and apply an antibiotic ointment (see figure 3-11).

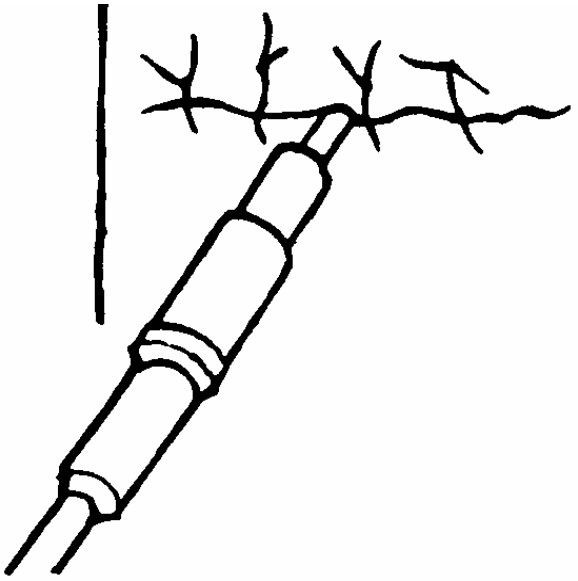

Figure 3-11. Suture incision.

(13) Apply a sterile dressing and tape the catheter in place.

(14) The procedure must be documented (usually in Nursing Notes). Physician will specify when to remove the skin sutures.

(15) Outer tape should show catheter size, date and time of insertion, and inserter's initials.

Continue with Exercises

EXERCISES, LESSON 3

INSTRUCTIONS: Answer the following exercises by marking the lettered response that best answers the exercise, by completing the incomplete statement, or by writing the answer in the space provided at the end of the exercise.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. What is the difference between the two major types of intravenous fluids?

   _____

   _____

2. An example of a hydrating solution that contains no calories is:

   a. Normal saline.

   b. D5W.

   c. D5RL.

   d. Intralipid^{R}.

3. If you can see suspended particles in an intravenous solution, you should:

   a. Use a filter on the administration set.

   b. Infuse at a slower rate.

   c. Use a larger bore needle.

   d. Discard the solution.

4. Scalp veins are often used as venipuncture sites for:

    a. Elderly persons.

    b. Women.

    c. Infants.

    d. Adult males.

5. The death of an intravenous therapy patient could easily result from:

    a. Using peripheral catheters.

    b. Using a small bore needle.

    c. An Infiltration.

    d. An air embolism.

6. The physician's order states that 500 milliliters of D5W should be infused over a four-hour period. Your infusion set delivers fifteen drops per milliliter. You will set the drip rate for ____ drops per minute.

7. The nurse started the intravenous infusion hurriedly just before you arrived. When you walk in, he hands you the patient's chart, telling you to check and possibly reset the drip rate while he administers medication. The administration set is giving ten drops per milliliter. The physician has ordered that the patient receive one thousand milliliters of the intravenous solution over a four-hour period. The drip rate is now set at thirty-five drops per milliliter. You should reset the drip rate to _____drops per milliliter.

    a. 42.

    b. 65.

    c. 24.

    d. Leave the drip rate as now set.

8. Blood cells in a unit of blood will all be dead within:

    a. 10 days.

    b. 21 days.

    c. 120 days.

    d. 24 hours.

9. One major advantage of using Normal Human Serum Albumin is that it:

    a. Draws fluid into the tissues from the blood vessels.

    b. Does not require refrigeration.

    c. Contains no water.

    d. Contains many red blood cells.

10. Although a blood product is usually transfused through the larger veins, it can be administered through other routes.

    a. True.

    b. False.

11. An example of a donor transmitted disease transmitted from a blood transfusion is:

    a. Hypothermia.

    b. Immunoglobulin.

    c. Rubeola.

    d. Malaria.

12. Blood that is being transfused should be warmed if:

    a. Massive amounts are being transfused at once.

    b. The blood unit is cold.

    c. Other solutions are being infused at the same time.

    d. The patient needs only minor surgery.

13. The transfusion information on a patient's record should be signed by:

    a. The head nurse.

    b. The physician.

    c. The person who gives the transfusion.

    d. The blood bank executive officer.

14. Common blood tests are performed mainly for the purpose of:

    a. Diagnosing disease in the absence of a medical physician.

    b. Determining a patient's food allergies.

    c. Determining a need for further testing.

    d. Administering special drugs.

15. The needle for venipuncture should be inserted at an angle of:

    a. 90 degrees.

    b. 20 to 30 degrees.

    c. 5 to 10 degrees.

    d. 180 degrees.

16. When an intravenous infusion is discontinued, you should record:

    a. Physician's name, your name, and when you finished.

    b. Why you stopped the infusion.

    c. Amount infused, amount left, time finished, and problems.

    d. When the infusion was started, how long it took, and the drip rate used.

17. Medication added to an intravenous container must be:

    a. A non-irritating type.

    b. Very cold.

    c. Mixed thoroughly with the solution.

    d. Added by the physician only.

18. If venipuncture is used for blood, the needle used must be:

    a. 18 gauge or larger.

    b. 20 gauge or smaller.

    c. Blunt point.

    d. A special type used only for blood.

19. The proper temperature for storage of whole blood units is:

    a. One to six degrees Fahrenheit.

    b. One to six degrees Celsius.

    c. Six to twelve degrees Celsius.

    d. Normal body temperature.

20. A venous cutdown might be indicated when the patient is:

    a. Very fat.

    b. Very thin.

    c. An athlete.

    d. Somewhat nervous.

21. A venous cutdown requires the use of a:

    a. Blood testing set.

    b. Scalpel.

    c. Very sharp needle.

    d. Magnified scope.

22. A venous cutdown done by a physician is considered:

    a. Clean, but not sterile.

    b. Drug dependent.

    c. Major surgery.

    d. Minor surgery.

23. Suggested sites for a venous cutdown include:

    a. Above and below the elbow.

    b. The groin area.

    c. Under the armpit.

    d. The buttocks.

24. A local anesthetic is injected for a venous cutdown to:

    a. Deaden feeling at incision site.

    b. Sterilize the open wound.

    c. Deaden feeling in the vein.

    d. Apply the antibiotic ointment.

25. During a venous cutdown, the vein is tied off:

    a. Above the vein incision.

    b. Below the vein incision.

    c. Above and below the vein incision site.

    d. Using a hemostat.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES, LESSON 3

1. The infusion solution arrives ready to use from the manufacturer while the admixture has certain drugs added for the patient by the Pharmacy Sterile Products Section. (paras 3-2a and 3-2b)

2. a (para 3-4b(2))

3. d (para 3-7c)

4. c (para 3-9b(5))

5. d (para 3-11e)

6. 31 (7500 divided by 240) (paras 3-13, 3-14)

7. a (10,000 divided by 240) (paras 3-13, 3-14)

8. c (para 3-15)

9. b (para 3-16c(1))

10. a (para 3-17)

11. d (para 3-19b(3))

12. a (para 3-20d)

13. c (para 3-20e(6))

14. c (para 3-21)

15. b (para 3-24i)

16. c (para 3-25b(9))

17. c (para 3-23a(3))

18. a (para 3-26b)

19. b (para 3-26d)

20. b (para 3-28)

21. b (para 3-29a(2))

22. d (para 3-27)

23. a (para 3-29b)

24. a (para 3-29c(5))

25. c (para 3-29c(8))

End of Lesson 3

APPENDIX

GLOSSARY OF TERMS

A

AGGLUTINATION: To glue together or clot.

AMEBOID: Ability to wander through capillary walls into the surrounding tissue.

ANIONS: Negatively charged ions.

ANTIBODY: Protein substances developed by the body, usually in response to the resence of an antigen which has gained access to the body. Normal antibodies are also present in the circulation.

ANTIGEN: A substance which induces the formation of antibodies. An antigen may be introduced into the body or it may be formed within the body.

B

C

CATABOLISM: Energy released which results in the breakdown of complex materials within the body.

CATIONS: Positively charged ions.

CHARGE: Positive or negative valence.

COLLOID SOLUTION: Particles are dispersed throughout a liquid medium. These particles are organically complex substances which are much larger than crystalloids but not large enough to settle out of the liquid.

CRYSTALLOID SOLUTION: Containing crystal-like particles which pass readily through membranes. Unlike colloids, these particles are organically simple.

D

DIATHESIS: A constitution or condition of the body that makes the body react in special ways to certain external stimuli and makes a person more than usually susceptible to certain diseases.

DYSPNEA: Difficult or labored breathing.

E

ELECTROLYTES: Substances that break down into positively or negatively charged particles when placed in water.

EXCRETORY ORGANS: Those organs which throw off or eliminate waste products from the body. Examples are kidneys, bowels and lungs.

F

G

GRANULES: Remains of nuclei in three kinds of white blood cells. There can be up to five in a single cell.

H

HEMOSTASIS: Arrest of bleeding.

HOMEOSTASIS: The tendency of the body to maintain or achieve a normal state.

HYPERALIMENTATION: Total nutrition supplied directly into the body by intravenous route.

HYPERKALEMIA: Abnormally high potassium concentration in the blood.

HYPERTONIC: Solution that has a greater solute concentration than body fluids.

HYPOTHERMIA: A low body temperature.

HYPOTONIC: Solution which has a lesser solute concentration than body fluids.

I

ISOTONIC: A fluid which has the same tonicity as body fluids.

J

K

KCl: Abbreviation for potassium chloride.

L

M

MALAISE: A vague feeling of body discomfort.

mEq (Milliequivalent): The number of grams of a solute contained in one milliliter of a normal solution.

MICROEMBOLUS: Embolus of microscopic size (microemboli-plural).

N

NECROSIS: Cell death.

NEPHROSIS: Any disease of the kidneys.

O

OSMOTIC PRESSURE: The maximum pressure that develops in a solution separated from a solvent by membrane permeable only to the solvent.

P

PARENTERAL: A solution administered in some other manner than by mouth (intravenous, intradermal, and so forth).

PLASMAPHERESIS: To draw blood from a donor and return his red blood cell mass after removing plasma by centrifugation.

POLYCYTHEMIA: Increase in red blood cell mass or a decrease in plasma volume without change in red blood cell mass.

PRECURSOR: A substance from which another substance is formed.

Q – R

S

SYNTHESIS: Union of elements to form compounds (complex substances).

T

TONICITY: The concentration of a substance (solute) dissolved in water.

U

V

VENTRICULAR ARRHYTHMIA: Variation from the normal heartbeat involving the ventricles of the heart.

VISCOUS: The thickness or thinness of fluid (that is, a lubricating oil would be highly viscous).

W –X – Y – Z

End of Appendix